HYDRAULIC TABLES,

TO AID THE CALCULATION OF

WATER AND MILL POWER, WATER SUPPLY, AND DRAINAGE OF TOWNS,

AND

Improvement of Navigable Rivers;

TOGETHER WITH THE PROPERTIES AND STRENGTH OF MATERIALS; USEFUL NUMBERS, AND LOGARITHMS.

ALSO,

TIDE TABLES for 1852, 1853, 1854; TIDAL CONSTANTS;

WITH VARIOUS

PHENOMENA OF TIDAL RIVERS.

BY NATHANIEL BEARDMORE,

MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS; FELLOW OF THE GEOLOGICAL SOCIETY; MEMBER OF THE BRITISH METEOROLOGICAL SOCIETY; ETC. ETC.

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1852.

ERRATA.

Page xvi. *For lines*—

Severn Framilode to Hock Crib,	14 miles	8	(inches fall per mile).
Hock Crib to Sharpness Point	24 „	5	„ „

Read

Framilode to Hock Crib	8 miles	12·5	(inches fall per mile).
Hock Crib to Sharpness Point	8 „	14	„ „

Page lxxxi., line 2 of concluding remarks—
For date *read* data.

On table 19, page 36, last line but four—
For Irish Mile = 3038 yards,
Read = 2240 yards.

Page 6. Table 2, column 2,—against ·34, *for* 41·17, *read* 42·17.
„ „ column 4,—against ·55, *for* 86·69, *read* 86·89.

TO

JAMES MEADOWS RENDEL, F.R.S.,

PRESIDENT OF THE INSTITUTION OF CIVIL ENGINEERS

IN RECOGNITION OF HIS GREAT ABILITIES,

AND IN

TOKEN OF MANY ACTS OF KINDNESS

THROUGH AN ACQUAINTANCE OF TWENTY ONE YEARS,

This Work is Inscribed,

BY HIS OLD PUPIL,

THE AUTHOR.

PREFACE TO THE FIRST EDITION.

In the computation of hydraulic questions daily required by an Engineer, much labour is saved by the systematic use of Tables; the means of detecting errors are far greater than in isolated calculations; and the results, when tabulated, are more useful than any mere formula: the one shows the object attained—the other gives the means only.

In the following treatise, the author has endeavoured to extend the basis of hydraulic calculations, on which there should not be much difference of opinion, to systematic results; the Tables are reduced to uniform measurements throughout, and the range of computations for slopes, velocities, &c., are such as will be required in practice; the whole being expressed in decimal measures, which give great facility for application.

To these are added the general qualities of materials, with computations for the strength of iron beams of approved proportions, concluding with Tables of Numbers, &c., generally required in a treatise intended for ordinary use of the Practical Engineer. The powers, roots, and logarithms of numbers are appended in a simple and legible form, to save the labour of searching them from different works in the numerous requirements of the profession.

The computations of all the principal Tables are original, and have taken much time and labour. It would be scarcely possible to enumerate all the authorities; among others consulted are—Robison, Leslie, Bossut, D'Aubuisson, Rennie, &c.; without previous researches, it would be useless to

attempt a treatise of this kind, and therefore, probably, the suggestions of many have been useful, although not specifically acknowledged.

The leading object has been to induce a more general and systematic application of hydraulic formulæ to practice: for the principles, being subject to the laws of gravity, must be uniform; therefore, however varying the means and circumstances, the results should be consistent.

The remarks upon rain-fall and the produce of springs, have been made rather to give examples than to propound any particular theory. It is hoped that others may be induced to give their experience and facts, to throw more light upon the subject.

When time permits, it is intended to add a Supplement, containing a generalized view of the phenomena of tidal estuaries, as practically useful to the engineer, with some more extended remarks on the flow of water from large districts.

13, *Great College-street,*
Westminster, May, 1850.

PREFACE TO THE SECOND EDITION.

THE First Edition of this work was received with much greater favour than the author had at all expected; and by the kindness of his friends, the sale was large, for so technical a work. This will be the best excuse for the new form in which the book is offered. To extend the use of this edition as a hand-book for the Engineer, in matters relating to Hydraulics and Hydrodynamics, many new Tables have been constructed, and Tide Tables are inserted at the close of the book, chiefly compiled from the data offered in the annual Admiralty Tide Tables, and from the Nautical Almanac.

The Table of Constants for time and height of high water and mean spring range has been much extended, from various sources, including our own observations; where blanks are left, it will be easy to fill up as opportunity requires and offers.

The introductory remarks on the use of the Tables, have been amended, and more information is interwoven, chiefly on our English rivers—the drainage areas of the more important of which have been especially computed from the Ordnance Map. The original remarks on tides and rivers are limited, or otherwise we should have been travelling out of the scope of this treatise; experience and practice are the great guide; and therefore, to obtain the best data for practical results, we have carefully collated all the well-authenticated data within our reach or personal experience, and had them condensed into tabular forms. The author has to thank several professional friends—Messrs. Cubitt, Rendel,

Rennie, Simpson, &c.—for their kind assistance in permitting the use of, and communicating original papers. We have also to acknowledge accessible information at the disposal of Admiral Sir F. Beaufort, F.R.S., Captain Drinkwater Bethune, and Captain Vetch, of the Admiralty Harbour department, whose published reports contain good data—not omitting to mention Captain Beechey's very valuable published papers; others to whom we are indebted, are named especially when the information is due to them.

Considering the small extent of engineering literature, and the immense stores of knowledge constantly accumulating in the office of an Engineer, it is to be wished that more of these data were placed at the public disposal, for it is on such alone that any true theories can be constructed.

Both editions of this work have been got up among a multitude of other necessary avocations; and the laborious details of calculation have been carefully and I believe accurately worked out by assistants—Mr. A. Sanderson for the first, and Mr. R. Despard in the present edition.

September, 1851.

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REMARKS ON THE USE OF THE TABLES.

DISCHARGE OF SLUICES, RESERVOIRS, &c.—Table 1.

DESCRIPTION AND USE OF THE TABLE.

This Table is computed on the law that the velocity of a body, at any height expressed in feet per second, is as 8.04 times the square root of the height. When water falls freely under highly favourable circumstances, its velocity is nearly this theoretic quantity, and is represented in column B, in feet per minute, opposite various heights shown in column A.

The column C is calculated from a co-efficient $7.5\sqrt{h}$, and should be used for finding the effective velocity of water passing through orifices of the form of the *venâ contractâ*, through well-constructed bridges, and ordinary sluices with good side walls; very large and well-placed sluices; and through wide openings whose bottom is level with that of the reservoir. This table also gives the discharge through well-placed and large vertical pipes, and narrow bridge openings, by deducting 1-9th from the tabular velocities.

The column D is calculated from a co-efficient of $5\sqrt{h}$, and should be used for the effective velocity of water through sluices without side-walls, such as are used commonly upon mill-streams and rivers, undershot wheel gates, and canal lock or dock-gate sluices; except built under very favourable circumstances, an intermediate between columns C and D is sometimes useful.

RULES AND EXAMPLES FOR THE TABLE.

First.—When the area of the orifice and the head of water are given, to find the discharge in cubic feet per minute; *Multiply the number in the table of the column* C *or* D, *according to the case, by the area of the orifice expressed in feet and decimals.*

Examples.—The fall of water is .05 through a bridge which has 500 feet of sectional area; what is the discharge?

Tabular number of column C, opposite .05, is $100.3 \times 500 = 50{,}150$ cubic feet per minute.

The difference of level between the upper and lower ponds of a canal is 6 feet; what is the discharge with a sluice having 4 feet superficial area of opening?

The total height being 6 feet, and opposite 6.00 in column D, is $734.7 \times 4 = 2{,}938$, which divided by 2 for the mean discharge due to the height, gives 1,469 cubic feet per minute. If the lock be 100 feet long and 18 feet wide, it will hold 10,800 cubic feet of water, and consequently take 7.34 minutes to fill; this would be too long, therefore the lock should have two sluices, each of 4 feet area.

Second.—When the discharge and the area of the opening are given, to find the head required; *divide the given discharge in feet, per minute (adding* 1-8*th for pipes). by the area of the orifice in feet, find the result in column* C *or* D, *according to the case, and column* A *will show the head required.*

Third.—When the discharge and the head of water are given, to find the area of opening; *divide the given discharge (or half such with a head decreasing* to zero) by the tabular discharge opposite the given head (deducting* 1-9*th of column* C *for pipes) and the result will be the area of the orifice required.*

Examples may be worked from the former ones, thus:—Required the area of lock sluices to run 2,938 cubic feet per minute, with six feet difference of level; or, in other words, to empty a lock 100 × 18 in 3.67 minutes.

The tabular number for 6 feet of head, in column D. is 734.7, and the mean discharge for the gradually decreasing head of the emptying lock, will be half, or 367.3 cubic feet per minute; then $\frac{2938}{367.3} = 8$ feet area of sluice required.

A vertical pipe is required to discharge 138 cubic feet per minute, from a reservoir with 50 feet head; required the area and consequent diameter?

The tabular number opposite 50 feet of head is 3181.95, which reduced 1-9th is 2828.4. Then $\frac{138}{2,828} = .049$ for the area of the pipe, which by the table of areas will be found to be four inches diameter.

GENERAL RULES FOR DISCHARGE FROM SLUICES, TANKS, RESERVOIRS, AND VERTICAL PIPES.

First Case.—Multiply the square root of the given head in feet, by 450 (400 or 300) times the given area in feet; the result is the *discharge in cubic feet per minute.*

Second Case.—Divide the discharge in cubic feet per minute by 450 (400 or 300) times the area in feet; the square of the result is *the head in feet.*

Third Case.—Divide the discharge in cubic feet per minute by the product of 450 (400 or 300), multiplied by the square root of the given head in feet; the result is *the area of the pipe or opening.*

Note.—450 is the multiplier for bridges, &c.
400 „ pipes, &c.
300 „ ordinary sluices, &c.

---

* Where the orifice of the sluice is covered, as in locks and river sluices, the "head of water" is the difference of level between the respective surfaces; in other cases, the head is to be taken from the surface to the centre of the opening; and for bridges, or similar cases, the accurate difference of level between the water surface on the upper and lower side of the bridge. When water is drawn down, as out of a lock with a head gradually diminishing to nothing, the discharge will be as the maximum head in half the time; or in other words, for a head of six feet gradually diminishing to nothing, the main discharge will be half the tabular number (for 6 feet) per minute for the whole time. Other cases of reservoirs, &c., emptying or filling with an increasing or decreasing head, require intricate calculation, and we have therefore inserted in the Appendix some interesting problems from Hutton's Tracts which can be best understood by perusal.

The Rules and Tables above described, when carefully applied, will be found to meet all ordinary cases in practice. The observer will frequently find his sluices, &c., more or less favourably circumstanced, and he must exercise his discretion accordingly. Where there are very severe bends in pipes and culverts a loss of discharge is occasioned, which is treated of in another place.

DISCHARGE OF WEIRS OR OVERFALLS.—Table 2.

DESCRIPTION OF THE TABLE.

This Table is computed by the formula $d = 214 \sqrt[2]{h^3}$, where d is the discharge in cubic feet per minute, of one foot in width of the waste-board or cill of the weir, and h is the true height from the top edge of such cill to the surface of water where it is at rest, or nearly so. The principle of the formula is, that the curve of the water falling over is a parabola; consequently there can be discharged only two-thirds of the water which would pass the full section due to h; the constant 214 is two-thirds of 321, which has been found, by frequent trials, to represent the factor, to be multiplied by $\sqrt{h}$ for giving the mean velocity in feet per minute of water passing over an obstacle such as a waste-board. The constant 214 is consequently liable to some variation under favourable circumstances; for instance, where the weir is formed of a number of short bays, divided by beams. In these cases, the water passing the edges assumes the *vená contractá* form, and consequently the width of the opening should be reduced for the true quantity of water passing. These and other causes which may render the observation liable to error, must be treated with judgment, according to circumstances.

PRACTICAL APPLICATION FOR GAUGING.

The best way of gauging weirs is to have a post with a smooth head, level with the edge of the waste-board or cill; *to be driven firmly* in some part of the pond above the weir which has still water. A common rule can then be used for ascertaining the depth, or a gauge, shewing at sight the depth of water passing over, may be nailed on, with its zero at the level of the cill of the weir. The depths in the table are given in feet and decimals, as used in ordinary levelling: this unit abridges calculation, and is altogether better than measurement by inches, which has been the more usual custom. Among practical engineers, gauging by a weir has been always justly held to afford the most certain and efficient result, and especially for ascertaining the *comparative discharges* of streams, which, in cases of litigation and arbitrations, is often as important as ascertaining the *real quantity*. The plain rules for correct gauging should be, absence of wind and current, a good thin-edged waste-board, and a weir not so long in proportion to the width above it as to wire-draw the stream; for, in this case, the water will arrive at the weir with an initial velocity due to a fall which is not estimated in the gauging, and the result will be too small, in all probability. A weir, for correct gauging, should always have a free fall over; but there are sometimes cases where measurements are required with drowned weirs—so called when the tail water has risen

above the level of the cill. In this case we have two conditions to deal with; first, the water passing at a depth represented by the difference of levels of the upper and lower may be treated by this Table as a simple overfall; secondly, there is a section of water passing between the top of the waste-board and level of the lower water, whose mean velocity will be that due to the difference of level or head above-mentioned. The velocity and discharge of this portion of the weir can then be computed from column D, Table 1: the sum of the two will give very nearly the true discharge.

The application of the Table in constructing weirs for relief of flooded lands is obvious.

A paper has been lately read before the Institution of Civil Engineers, by T. E. Blackwell, Esq., the Engineer of the Kennet and Avon canal: it is on the eve of publication in their *Transactions*, and will be found well worth the study of those interested in these pursuits, as containing a condensed account of a vast number of experiments which must have taken great time and labour. The results of Mr. Blackwell's experiments seem to be, that under favourable circumstances, the constant by which the Table No. 2 is calculated, is substantially correct; that is to say, in a good situation for the flow of water approaching, and with a thin waste-board. With thick waste-boards, and narrow openings, the results are generally .80 of those which would be given by the Table.

One important and useful set of his experiments, are on weirs with a lip three feet wide, having an edge level, or with a small slope in the transverse section; this is a kind of case frequently met with in practice, and we find that the results of Mr. Blackwell's experiments give from .70 to .75 of the Tables; this is quite consistent with the allowance we have generally found it necessary to make, where so much friction is involved.

SURFACE, MEAN, AND BOTTOM VELOCITIES Of Rivers, Streams, and Estuaries.—Table 3.

DESCRIPTION OF THE TABLE.

This Table is computed from the formula $b = \overline{\sqrt{s}-1}^{\,2}$, where the velocity at the surface in the middle of a river is s, and that at the bottom b. The column of mean velocities is $\frac{s+b}{2}$; or may be found in an easier way by taking the mean velocity, $m = s - \sqrt{s} + .5$. In the formula, the velocities are expressed in inches per second, but in the Table they are reduced to feet per minute, which is made the unit throughout this work, where applicable to ordinary use and custom.

PRACTICAL APPLICATION.

The Table shews, by inspection, the relative velocities of streams of all kinds, extending from 5 to 950 feet per minute. Its most important use is for gauging any quantity of water passing down any river or stream. For this purpose, get the surface velocity at the central part of the stream, by observing, either with a current meter, or with floats barely reaching the surface, and offering no space to the action of the wind; their velocity being noted by fixed buoys or by marks upon shore. The mean velocity corresponding to that of the surface as then obtained, is, in fact, an imaginary quantity, representing the mean of the whole area of water passing

the place of observation; therefore, when the discharge of a stream is required, take cross sections where the channel is straight, and observe the velocity of the surface; look in the Table for the corresponding mean velocity, and multiply it by the area of the section in feet; the result will be the discharge in cubic feet per minute. If a current meter is used, take the velocity at the place of section; or if floats, take their time of passing between two sections; in either case repeating the observations at several places, for obtaining an average, and using the greatest judgment in selection of places for trial, for otherwise the whole is liable to be incorrect.

The bottom velocities are chiefly useful for shewing the permanent limit of the bank, &c., of a stream which may be required to be straightened or made *de novo*. If any river pass at a greater rate than the banks will bear, it is a beautiful law of nature, and most certain in its effects, that a greater sectional area is cut out; and thus the hydraulic mean depth being increased, the surface slope becomes flatter, and the general velocity and scouring action is reduced. It is most essential to the success of artificial cuts that their bottom velocities should not exceed the permanent limit of the material through which they pass. The first action of this kind destroys the whole economy of a work,—deepening unequally is commenced,—eddies and shoals must follow, and inequality of water surface accompanies the evil, reproducing these effects.

The second page of this Table is headed by a statement of the effect of bottom velocities on materials through which rivers usually are cut, and they form a criterion for the limiting bottom velocities of new cuts. It will be found, however, that the Table somewhat over-rates the effect produced by currents when applied to rivers as they exist; for there are constant occurrences of higher velocities than these, offering no permanent damage to the bed of rivers; in point of fact, the bottom invariably becomes covered with weed or slime, which much prevents the effect of abrasion.

The most useful instrument for getting velocities, where a float is not applicable, and where an under current is probable, is the current meter, formed by a vane in the Archimedean form, carrying an endless screw, which turns a wheel divided on the circumference. We have had one made lately with a second or differential wheel, worked by the same screw, having one tooth less than the first, and shewing in its revolution about 1,128 turns of the first wheel; this gives the power of leaving the instrument under water for a considerable time, which is frequently very desirable for obtaining a good mean velocity. In gauging by velocities, care should be taken to ascertain that the current does not under-run at the place of observation. This phenomenon frequently occurs in rivers and tidal streams, where the passage is narrow and deep, the latter generally an effect of the under-current rather than a cause. At sharp bends of large rivers, and at headlands on sea-coasts, this generally occurs, and is detected on the surface by the races which are formed. Striking instances may be seen off the Isle of Portland, and some of the bold headlands of Cornwall, Wales, and the north and west of Ireland and Scotland.

ARTERIAL DRAINS, RIVERS, &c.—Tables 4 & 4a.

The rule on which this table is constructed is—multiply the hydraulic mean depth in feet by twice the fall in feet per mile; take the square root of the product and multiply it by 55; the result is the mean velocity of the stream in feet per minute; this again multiplied by the sectional area in square feet, gives the discharge in cubic feet per minute. The hydraulic

mean depth is obtained by dividing the sectional area of the stream by the border or wetted perimeter: in pipes this is simply one-fourth of the diameter. The table is arranged for falls of 2, 3, 4, 5, 6, and 9 inches, per mile, but, by referring to the short table at the commencement of page 8, it can be readily extended to 12 more rates of fall per mile—and even further extended by using the following rule, viz.: the velocity and discharge varying as the square root of the fall, *half the discharge or velocity of any given fall* will be the discharge or velocity for *one-fourth that fall;* or vice versa, *for the discharge or velocity of four times any given fall per mile,* take twice the discharge or velocity of such fall.

Table 4*a* is given chiefly for application to large rivers, and it will be found to include in its dimensions some of the greatest examples. As applied to tidal rivers it shows that enormous power of discharge is given to large sectional areas, however small the fall, simply because the tabular results are based upon *uniform construction and regular beds.* Having analysed numerous actual observations of rivers, the author has never found the rule for this table at fault, when the conditions were fairly represented in the experiments.

The application of these tables to cuts of all kinds for straightening rivers, for forming mill heads and carrying off flood waters, is sufficiently obvious. The tables shew the slopes that rivers of various sizes will assume under the laws of gravity influenced by friction of the bed; giving by mere inspection what would otherwise require tedious computation.

The following Statement of Falls of Lincolnshire Drains, &c., is by Mr. Utting, of Wisbeach, the Surveyor to the Nene Outfall Commissioners.

Fen land ranges from 8 to 14 feet above the level of low water at sea.

On the river Ouse, between February 21st and April 2nd, 1848, during the prevalence of the heaviest flood that had occurred for several years, the average fall per mile on the surface of low water, from Denver Sluice to Free Bridge, was under 7¾ inches per mile, and the maximum inclination was, on March 23rd, less than 9 inches per mile. Also, during the six weeks' flood, from October 9th to November 19th, 1848, the average fall was less than 7″ per mile, and the maximum under 9″ per mile. During the fourteen weeks, from November 15th, 1847, to February 20th, 1848, the average fall was 6¼ inches per mile; and from November 15th, 1847, to April 16th, 1848, the average fall was less than 7 inches per mile.

On the 16th July, 1849, the total fall from Denver Sluice to Free Bridge, was only 2′ 9″, or 2.6 inches per mile, for 12 miles 5 furlongs.

In the Nene, between the North Level Sluice and Sutton Bridge, the fall in the ordinary state of the river does not exceed 1½ or 2 inches per mile; and at the height of the flood of March, 1848, it did not exceed 4 inches per mile: and at the same time, the fall from the Horseshoe to the North Level Sluice (4¼ miles), was only 6″ more than ordinary. Below Sutton Bridge, the fall is ordinarily about 1 inch per mile, though the surface of low water is frequently level.

From March 13th to 26th, 1848, low water at Sutton Bridge, was, on the average, 4′ 8″.6 lower than at Free Bridge.

The original dimensions for the upper end of the Nene outfall cut, were 410 feet wide at top, or at the level of high water spring tides; 250 feet wide at bottom, and 20 feet deep; giving an area of 6597 square feet.

The Eau Brink cut, at spring tides, has 5535 square feet of sectional area.

GENERAL APPLICATION TO RIVER IMPROVEMENTS.

The following TABLE of the CHARACTERISTICS OF RIVERS, from the *Phil. Trans.*, gives a good outline of their general conditions.

The velocities and inclinations shew what may be expected under given conditions, and will be thus practically useful; it will be found to describe well the nature of the rivers of Great Britain, which frequently embrace in their course nearly all the eight descriptions. The insertions in blacker type are the author's.

CHARACTERISTICS OF RIVERS.	Velocity in Feet per minute.	Inclination. Inches per Mile.
First.—Channels where resistance from the bed and other obstacles equal the current acquired from the declivity; so that the waters would stagnate were it not for the impulse of back water	**50** to 120	**2.00** to 5.28
Second.—Rivers in low flat countries, full of turns and windings, and of a very slow current, subject to frequent and lasting inundations	60	12.18
Third.—Artificial canals in the Dutch and Austrian Netherlands.	**30** to 40	**2.00** to 9.05
Fourth.—Rivers in most countries that are a mean between flat and hilly, which have good currents, but are subject to overflow; also the upper parts of rivers in flat countries	90	15.84
Fifth.—Rivers in hilly countries, with a strong current, and seldom subject to inundations; also all rivers near their sources have this declivity and velocity, and often much more	130	19.8
Sixth.—Rivers in mountainous countries, having a rapid current and straight course, and very rarely overflowing......	180	24.37
Seventh.—Rivers in their descent from among mountains down into the plains below, in which plains they run torrent-wise ...	300	31.68
Eighth.—Absolute torrents among mountains	480	37.27

The following is a TABLE of the SIZE, VELOCITY, and FALL of several IMPORTANT RIVERS.

It is compiled from Mr. Rennie's Reports on Hydraulics; the English Rivers from the Author's Notes; those marked (a) from a paper by Mr. David Stevenson, C.E., Edinburgh; the Nile is from some late remarks made at the Institution of Civil Engineers, by Robert Stephenson, Esq., M.P.

NAME, DESCRIPTION, AND SECTION OF RIVER.	Surface velocity. Feet ℔ Min.	Fall per Mile. Inches.
Dee, lower part above Chester...............(a)	......	11
Lune „ „ Lancaster............(a)	......	23
Forth „ near Stirling...............(a)	......	13
Thames average—Oxford to Teddington, including weirs	176	21
„ Hampton Court ....160×6	143	below weir
„ Below Staines Bridge.........160×7	130	3·73
„ „ „ more water, 160×8	101	1.50
„ Hurley (deep section) ......166×11	40 to 50	between weirs
Severn, Worcester to Gloucester......150×16	190	5·
„ Gloucester to Longney ......10 miles.	......	1.25
„ Longney to Framilode ...... 2 „	......	9·
„ Framilode to Hock Crib ...14 „	......	8.
„ Hock Crib to Sharpness Pt. 24 „	......	5·
„ Sharpness to Old Passage...15 „	......	12.
„ Old Passage to King's Road 8 „	......	nearly level
Shannon, Limerick to Lough Allen............	......	12
Nene, above Peterborough, below weirs...(b)	50 to 70	5 to 12
„ Northampton to Wansford average	......	38.7valley
„ Wansford to Peterborough, average	......	21.8valley
„ Peterborough to Guyhirn ......44×5·5	66	2.0
„ New Cut at Cross Keys Wash	......	4·9
Eau Brink Cut, in Norfolk	......	5·0
Drains, in Lincolnshire	......	5·0
New River—18×4.4 (fall including sluices)	50 to 60	5·0
„ „ (fall of surface).........	„	2·5
Seine, at Paris (mean depth 3.6 feet)	......	9 to 12.67
„ Paris to Havre, mean	125	12·4
Loire, between Pouilly and Briare	......	8·4
„ „ Briare and Orleans	......	4·6
Rhone, from Besancon to the Mediterranean	......	24.18
Lys and Scheldt	......	9·5
Canals in Flanders..................................	275	6·33
Po..	......	6.
Rhine, between Schaffhausen and Strasburg	......	48.
„ „ Strasburg & Schenckenschantz	......	24.
Canal of Pius 6th—Ordinary state: 1st length	......	17·23
2nd length	......	4·31
„ „ Flood time: 1st length...	.....	16.47
2nd length...	......	5·76
Uffente...	......	3.1 to 6.0
Amazon	......	2.34
Ganges (valley 9 ins. per mile), dry season...	264	4·
„ rate of inundation, at Rajmahal (c)	44	
Neva, at St. Petersburgh ....900×63	156	1.7

(b) (b) The fall in this river is to a great extent absorbed by mills; water surface is from 3 to 12 inches per mile; the river floods excessively.

(c) The fall of the Bhaugiruttee, between Rajmahal and the Mirzapore Creek of the Hoogly is............3.873 inches per mile—length 190 miles.
Fall of the Valley is 4.970 „ „ 129 „

The fall of the Nile, when high, is 68 feet from Cairo to the Mediterranean, or about 5 to 5½ inches per mile, with a velocity of 300 feet per minute occasionally. When the Nile is low, its fall is 3½ inches per mile, or a total of 42 feet between the above points, with a velocity of 110 feet per minute.

		Feet Wide.		Feet Deep.
The section of High Nile at Cairo is about	......	1100	×	40
„ Low Nile „	......	900	×	14

The fall from Cairo to the Barrage, at High Nile, is 4 inches per mile.
„ „ at Low Nile, is 5 „ „
At the Damietta Mouth, High Nile raises the level two feet.

CIRCULAR AND EGG-SHAPED CULVERTS.
Tables 4b & 4c.

Table 4b gives the discharge and velocity for culverts from 8 feet to 1 foot in diameter, as if half full and three-fourths full; showing also the area of water-way at such depths respectively. The data given are with inclinations from 2 to 7 feet per mile, which will embrace the usual practical range. It is computed by the formula as described for table 4, but it does not differ materially from the results obtained from table 5, although the method of computation is totally different.

Table 4c gives the same information in every respect as table 4*b*, for oval culverts; the vertical and transverse dimensions are given in the first column; in table 4*b* will be found circular culverts of the same sectional areas while half full and three-fourths full, so that a comparison is afforded of the discharge of the circular and oval form.

PIPES UNDER PRESSURE.—Table 5.

This is a universal table* for the discharge of pipes and culverts from one inch to ten feet in diameters from one inch to ten feet; its mode of use is explained on the table, the constants merely require to be divided by the square root of the rate of fall to give the discharge in cubic feet per minute.

The formula is $\dfrac{2{,}356 \times \sqrt{d^5}}{\sqrt{\dfrac{l}{h}}}$ = discharge in cubic feet per minute.

Where d = diameter of the pipe in feet, h = head in feet, and l = the length in feet, and 2,356 is a constant.

If the velocity in feet per minute is required for a given fall and diameter of pipe, divide the discharge (as found by the table) by the area of the pipe, expressed in square feet.

If the head is required for a given discharge, length, and diameter of pipe, divide the tabular number of the diameter by the discharge, and square the quotient; then divide the length by this number, and the result will be the head in feet.

EXAMPLE.—A pipe 2 feet in diameter and 5,000 feet in length, is required to carry 300 cubic feet per minute, what should be the head ?

Tabular number for 2 feet pipe $= \frac{13.327}{300} = 44{\cdot}4$; then $44{\cdot}4^2 = 1{,}971.3$ and $\frac{5000}{1971.3} = 2.54$ feet, *which is the head required.*

If the diameter of pipe is required for a given head, length, and discharge, then $\cdot 235 \sqrt[5]{\dfrac{l \times q^2}{h}}$ = diameter in feet, l and h being as before, and q being the quantity discharged *in cubic feet per second.*

This last is a tedious formula, and the table gives the same result for a vast range of discharges, by following the second rule thereon.

Where culverts are not circular, take the diameter corresponding to a circle of the same sectional area, and the result will be very *nearly correct.*

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* The design of this table is due to Mr. James Leslie, C.E., Edinburgh, who has kindly permitted its use. The table is entitled "Pipes Under Pressure," as particularly adapted for such use; but it is also applicable to Culverts, &c., of course apportioning the amount filled, whether half or three-fourths, and having due reference to the slope not creating too high a velocity and over gorging.

PIPES UNDER PRESSURE.—Table 5a,

Gives, by inspection, the discharge and velocity for pipes from 3 to 60 inches in diameter, and at rates of fall from 5 to 35 feet per mile. The table is computed from the formula of table 5, and will be found useful for ready inspection, besides which the knowledge of comparative results is highly desirable when designing works or computing their probable effect.

In using these tables we must repeat a caution given elsewhere, that a due feed into a train of pipes, absence of inequality in slopes, of sudden bends, &c., are highly necessary to obtain a proper discharge. Under proper conditions we are inclined to believe that small pipes will be likely to give a less result than the tables, and large pipes a greater result.

For pipes under pressure, 200 feet per minute is a very good working velocity, giving probably better proportional discharge than greater fall and consequent speed is likely to do; a velocity of 150 per minute will generally prevent deposit in pipes and sewers.

The foregoing table will meet cases of pipes and culverts, under simple conditions; but where bends (*see friction of bends*) and other complications are introduced, calculation becomes extremely difficult. The following experiments and facts from practice, are inserted so as to throw light upon the loss of head in town supplies, and the effective value of pressure through long ranges of street main.

EXPERIMENTS ON THE HEIGHT AND DISCHARGE OF JETS,

By the Southwark Water Company, January, 1844.

Pressure at Battersea 120 *feet, and every service pipe or other outlet kept shut.* *Stand Pipes* 2½ *inches diameter.*

First Experiment—in Union Street, between High Street and Gravel Lane, Borough, through stand pipes, hose, and jets; there being six stand pipes, each 360 feet apart, connected to a 7-inch main 2,400 ft. in length,

the head being carried on through a	9	„	„	1,500	„	„
„ „	12	„	„	600	„	„
„ „	15	„	„	1,650	„	„
„ „	20	„	„	10,350	„	„

Making a total distance of......... 16,500 feet from the Head at Battersea.

Second Experiment—in Tooley Street, 9-inch main 4,200 ft. in length,

the head being carried on through a	15	„	„	3,000	„	„
„ „	20	„	„	12,750	„	„

Making a total distance of......... 19,950 feet from the Head at Battersea.

Remarks on the use of the Tables.

	Standpipes used.	Length of Hose.	Diameter of Jet.	Height of Jet.	Discharge per Minute.
	Number.	Feet.	Inches.	Feet.	Cubic Feet.
First Experiment.	1	40	$\frac{7}{8}$	50	15.7
	2	40	$\frac{7}{8}$	45	—
	3	40	$\frac{7}{8}$	40	—
	4	40	$\frac{7}{8}$	35	—
	5	40	$\frac{7}{8}$	30	—
	6	40	$\frac{7}{8}$	27	—
	1	80	$\frac{7}{8}$	—	16.6
	1	160	$\frac{7}{8}$	40	16.0
	1	40	$2\frac{1}{8}$	—	42.1
Second Experiment.	aa 1	40	$\frac{7}{8}$	40	13.17
	aa 2	40	$\frac{7}{8}$	31	10.90
	bb 1	40	$\frac{7}{8}$	34	11.98
	bb 2	40	$\frac{7}{8}$	23	9.30
	1	40	$\frac{7}{8}$	60	17.15
	2	40	$\frac{7}{8}$	60	—
	4	40	$\frac{7}{8}$	45	14.90
	6	40	$\frac{7}{8}$	40	13.80

aa are through 600 feet of 5-inch main, but fitted on a 4-inch main close to the 5-inch main; *bb* are through 600 feet of 5-inch main and 600 feet of 4-inch main, both in addition to the 19,950 feet of main before described.

EXPERIMENTS ON THE HEIGHT AND DISCHARGE OF JETS,

By the Preston Water Company, March, 1844.

From 6-*inch Main.* *Pressure* 110 *feet.*

		Height.	Discharge.		
With 1 jet..	$\frac{3}{4}$-in...	57 feet....	12.5 cub, ft.	per min.	by day.
" 1 " ..	"	64 "....	14.4	"	by night.
" 2 jets	"	56 "....	12.5	"	by day.
" 2 "	"	62 "....	14.0	"	by night.

From 6-*inch Main.* *Pressure* 46 *feet.*

		Height.	Discharge.		
With 1 jet..	$\frac{3}{4}$-in...	24 feet....	4.8 cub. ft.	per min.	by day.
" 1 " ..	"	..28 "....	5.6	"	by night.
" 2 jets	"	..20 "....	4.5	"	by day.
" 2 "	"	..25 "....	4.8	"	by night.

At Leeds, the author has seen jets thrown 60 to 70 feet high, and with great body and force, 40 to 50 feet high in the lower part of the town, where the pressure was 180 feet, and services in full draught.

At the West Middlesex Water Works, from experiments by W. T. Clarke, Esq., the friction of the pipes was found to reduce the head of water between one-fourth and one-fifth.

The Grand Junction Water Company's new engine at Kew, works against 205 feet of head, while the gauge on the other side of the stand, (indicating the back pressure from London,) gives only 170 feet; showing a loss of 35 feet head, by the draught on the great 45-inch main.

At New York the height of the water is 115 feet above high water;

105 feet above the lowest, and sixty feet above the highest streets. The distance from the distributing reservoir is 4 miles, by a direct 36 inch main. The city fountains throw from 60 to 70 feet high. At Harlaem River Valley, on the line of the aqueduct, a 12″ pipe and 6″ jet throws the water 110 feet high, with 180 feet pressure.

At Philadelphia the surface of water in the reservoirs is 98 feet above high water; 55 feet above the highest, and 93 feet above the lowest points in the city. The distance from the reservoir to extreme point of mains and pipes (which are always charged), is 6 miles, by a main from 20″ to 22″ diameter. The loss of head, by friction in the pipes, is about 25 feet while the city is drawing. The mains are from 10 to 12 inches in the principal streets, and from 4 to 6 inches in the minor ones.

The water will rise from a hose attached to a fire-plug in the streets at the extreme point of delivery, during the night, to the height of about 45 to 50 feet; during the day, when the consumption of water is very great, the pressure is about 25 feet, as above stated.

THE FOLLOWING TABLE is from experiments by Mariotte. The first and second columns give the relative height of jets and their head; the third column gives the discharge by an ajutage .53 inch diameter, and the fourth column contains the diameter which ought to be given to the service pipes for an ajutage of .53 inch, relatively to the altitudes in the second column. They are computed on the hypothesis that for an ajutage of .53 inch in diameter, and an altitude of 16 feet of water in the reservoir, the conduit pipes must be 2.49 inches in diameter, and upon the principle that the squares of the diameters of the conduit tubes are as the squares of the diameters of the ajutages multiplied by the square roots of the altitude of water in the reservoir. These experiments are considerably at variance with those made in the foregoing tables, in Southwark, &c., especially while water is being drawn for other purposes; they were probably made under circumstances considerably differing from the ordinary demands of practice.

Height of Jet.	Height of Reservoir.	Dis. per min. from ajutage .53-inch diameter.	Diam. of services suited to preceding column.
Feet.	Feet.	Cubic Feet.	Inches.
5.32	5.41	0.89	1.87
10.68	11.00	1.25	2.31
15.97	16.77	1.55	2.49
21.30	22.71	1.80	2.76
26.62	28.84	2.03	2.93
31.95	35.14	2.25	3.02
37.27	41.62	2.44	3.20
42.60	48.27	2.64	3.29
47.92	55.11	2.80	3.38
53.25	62.12	3.00	3.47
58.57	69.31	3.17	3.56
63.90	76.68	3.33	3.65
69.22	84.22	3.47	3.74
74.55	91.94	3.64	3.83
79.87	99.84	3.78	3.91
85.20	107.91	3.94	4.00
90.52	116.17	4.08	4.09
95.85	124.60	4.22	4.18
101.17	133.21	4.39	4.27
106.50	141.99	4 53	4.36

FIRE ENGINE POWER.

The best form of London engine has two cylinders of 7 inches diameter and 8 inches stroke, working levers being $4\frac{1}{4}$ to 1; weight $17\frac{1}{2}$ cwt. + 4 cwt. for hose and tools, which is quité as heavy as two fast horses can manage, for a distance under 6 miles, with five firemen and a driver,

The rule for determining the size of the jet, is to make its diameter one-eighth of an inch for every inch diameter of the cylinder for each 8 inches of stroke. When it is necessary to throw the water to an unusual height or distance, a jet one-seventh less in area is used, with a branch about 5 feet long.

The usual rate of working an engine this size is 40 strokes of each cylinder per minute, the engine throwing 14.12 cubic feet per minute, or, adding one-third for waste, 6,777 cubic feet required for 6 hours; this multiplied by the number of engines used, will give an idea of the quantity of water required at a fire. When the houses of Parliament were burnt down, 522,720 cubic feet of water was supplied, and 23 jets were playing at one time.

With 40 *feet of leather hose, and a $\frac{7}{8}$-inch jet, the pressure is* 30 *lbs. on the square inch* = 68 *feet head of water;* this gives 10.4 lbs. to each man to move a distance of 226 feet in one minute. The friction for every additional 40 feet of hose increases the labour $2\frac{1}{2}$ per cent.; hence the necessity of having the engine, and of course the supply of water, close to the fire.—(Braidwood, &c. Min. Inst. Civ. Engrs.)

FRICTION OF BENDS.—Table 6.

DESCRIPTION OF THE TABLE.

This table is computed on the formula $h = v^2 \times \text{sine}^2 \times n \times .0003$, where v is the velocity of water in a pipe or stream, expressed in inches per second; or in words; multiply the square of v by the sum of the squares of the sine of the angle of bends (of which the resistance is to be estimated) and the product by the constant .0003; the result expresses the resistance h = the head in inches necessary to overcome the angular friction, which varies as the square of the velocity and of the sine of the angle of bend with the straight line of direction. When the angle is reversed, or more than 90°, the square of the sine of the complementary angle + 1 must be used. The rule was adopted by Robison, from French experiments made upon pipes of small diameter, and he shows its applicability to rivers, giving an opinion that the measure of resistance is too great, as "in a pipe the diameter is uniform, whereas in a properly formed river, the capacity of section should be increased." This, theoretically, is true; but, practically, it is certain that both in natural and artificial rivers, the effect of bends is invariably to render the bed more or less uneven. Under all the considerations, we may, therefore, come safely to the conclusion that the friction of bends, even where a drain is kept in good order, is at least as high as the amount given in the table.

The velocity for computation is of course that theoretically due to the fall, and the loss by bends must be deducted from the head, the discharge being again calculated from the reduced slope. The loss of head, however, manifestly varies not only according to the size of the angle, but also to the volume to be carried. Applying the principles adopted in the

former tables, the variable term of resistance will be best expressed by the square root of the hydraulic mean depth in feet, and the loss of head should be divided by this quantity to give the final resistance. By this form of the equation, when the hydraulic mean depth falls below unity, the tabular numbers are increased as the square of such depth. With pipes, this quantity being one-fourth of the diameter, the increase of resistance h will be $= \dfrac{v^2 \times \text{sine}^2 \times n \times .0003}{\sqrt{\frac{d}{4}}}$ This modification in the formula is new, and the whole computation is highly theoretical; but it sufficiently agrees with experiments and with observation to be worthy of note. The principle of the correction is well founded where bends are uniform; but when they are made at sharp angles, the experiments of Mr. Rennie clearly show that they are out of the reach of calculation.

Taking the second example at the head of the table, and applying it to a drain having 6 feet depth, 18 feet bottom, and 2 to 1 slopes, we find by table 4, that with a velocity of 110 feet per minute, such a cut will discharge 19,803 cubic feet per minute, and require six inches per mile of fall; we have then, for the bends specified, to make a reduction (in round numbers) of one inch fall per mile, if they occur in that length; but this quantity will have to be divided by 2, which is the square root of the hydraulic mean depth of the drain in question. Therefore to deliver the same quantity of water, the drain must have 6.5 inches fall in the mile; or, *vice versa*, if the fall is limited, the effective slope will be reduced to 5.5 inches per mile, and the discharge to 18,915 cubic feet per minute, with a mean velocity of 105 feet per minute, instead of 110 feet, as originally assumed.

Bends in the vertical plane are subject to disturbance of the discharge from two other causes, which will interfere far more than the dynamical effect of change of direction. The first is the great tendency to collection of air at the summit of vertical bends; this evil can only be treated mechanically, by air valves, which will free themselves, or can be opened at the pleasure of the water officer. The second defect in vertical bends is when from local circumstances they occur on a pipe at any given distance B, from the fountain head A; this point not being sufficiently high above B to pass the full quantity of water which could otherwise pass on to a lower point C; under these conditions it will be impossible for the pipe to discharge at C the amount due to its diameter, and to the *total fall from* A *to* C; and neither can the fall be fully available from B to C, because there will not be sufficient feed at B. This obviously shews that under these circumstances the pipe A B must be larger than B C; neglect of such a precaution has frequently produced serious disappointments; excellent provisions against the evils above stated were made by Mr. Jardine of Edinburgh, in the great main, ten miles in length, which he constructed twenty-seven years since; the upper three miles being flat, is 21 inches in diameter, but the lower portion is only 15 inches diameter; the actual discharge at Edinburgh is not greater than would be given by a pipe only the smaller diameter, with a *uniform fall for the entire distance.* This main was one of the earliest works in iron on so great a scale, and the whole arrangement is a model of its kind; at the present price of iron, such a work would not cost more than one-third of the amount then disbursed, but the value of this kind of construction may be judged from the fact that this main has not cost anything whatsoever in repairs, and has never ceased delivering water from the day it was finished up to this date.

Other causes will arise to lessen discharge, unless due precautions are taken in the form of inlet and outlet of pipes; which will evidently

affect the final delivery. The preceding rules and tables will meet all ordinary cases of practice, if the work is well laid out, and care is taken to avoid sharp angles and vertical bends, rising near to the level of the original head. If the form of nozzles or sluices starting from a reservoir is bad, the calculated discharge will be diminished in Etelwein's proportion of 8 to 6 or 5, however much labour or money be spent on the general line of works.

River Bends are especially liable to banks or shoals, always occurring where an alteration of velocity is suddenly caused; these shoals act as weirs, in point of fact, forming separate steps in the surface fall, and thus rendering a great aggregate slope of less value than a very small slope, with uniform bed. The effect therefore of bends, and want of uniformity, is of the highest inconvenience in rivers (like the Severn, below Gloucester, for instance) where there is a great fluctuation in the quantity of water, and a shifting material in the bed of which it is composed. The uneven bed of a river is very analogous to the defect from bends in the vertical plane, in the case of pipes.

FRICTION OF BRIDGES AND PIPES.—Tables 6a.

The first table is explained thereon, as giving an approximate idea of the rise of water caused by bridges, weirs, &c., at varying velocities; taking the proportions of obstruction from one-tenth to six-tenths of the whole section of river.

The second table is that used by Smeaton, giving the head required to drive water at various velocities through 100 feet lineal of pipes; on a small scale the table is useful; but our tables 5 and 5a will give a greater range of results, and agree more with the modern practice of laying mains, and their sizes and material.

VALUE OF WATER POWER.—Table 7.

This table gives the nominal value in horse power for one foot of fall of streams, discharging from 5 to 10,000 cubic feet per minute; *i. e.*, the weight in pounds of the given number of cubic feet, per minute, divided by the constant 33,000. The effective value of the ordinary applications of water is given according to the best authorities. In estimating the value of a given quantity and fall of water, the mode of application and therefore the commercial effect, will vary considerably; for in low falls under-shot or breast-wheels must be used, which are far more wasteful of water than over-shot wheels (in proportion to the power developed), especially when liable to be loaded with tail-water. The column headed "Turbine" is computed at 75 per cent. of the nominal power or actual weight of water consumed. The "turbine," and some very perfectly constructed overshot wheels are said to do this amount of duty.

THE FOLLOWING TABLE of Water-Wheels, as constructed by Mr. Fairbairn, of Manchester, will afford a useful practical example of the best applications of Water Power. (Jamieson's *Practical Mechanic.*)

Fall of Water	Cubic Feet of Water taken per Min.	Diam.	Breadth	Depth of Bucket.	Revols. per Min.	Speed of Periphy. per Min.	Estimated Horse Power	Diam. of internal Driving Segment	Breadth and Pitch of Teeth.
Ft. In.		Ft. In.	Ft. In.	Ft. In.	Ft. Dec.	Ft. Dec.		Ft. In.	In.
..	..	65 0	6 0	1 0	..	..	..	63 3	10×3½
33 2	..	36 0	16 7	1 4	1.95	214.8	..	33 8	14×3
26 6	..	28 0	13 0	1 10	..	..	..	..	..
16 6	2760	20 0	17 0	1 8	..	229.2	60	18 0	12×3¼
13 3	..	18 0	21 0	1 8	4.78	270.0	..	16 1	14×3
16 0	2160	18 0	20 0	1 6	..	..	52	..	..
10 0	..	18 0	18 0	1 10	6.15	339.6	..	14 0¾	12×3
16 0	1200	18 0	12 0	1 5	..	..	30	..	..
9 0	6960	16 0	21 0	2 0	..	..	70	14 0¾	..
7 10	..	16 0	20 0	1 9	7.8	384.6	..	15 4½	8×3
9 6	2700	16 0	18 0	1 8	..	330.0	..	14 0	12×3
..	..	16 0	16 0	2 0	..	..	..	14 0	12×3
8 0	..	16 0	14 9¼	1 9	..	375.0	..	14 0¾	9×3
8 0	..	15 6	17 6	1 8	..	332.4	..	..	..
14 6	480	15 0	6 0	0 10	..	..	12	..	..

THE FOLLOWING TABLE is compiled from a tract by Weale, of experiments by the late Mr. Rennie, made about sixty years since. It was kindly put into the author's hands by George Rennie, Esq., F.R.S., the author of well-known works on hydraulics, which have been highly useful in compiling this treatise. The principal value is to show the actual water used by the variously-constructed wheels, as the water used appears to have been taken with great care.

Name and Description of Mill.	Fall of Water	Water Wheel.				Mode of taking Water.		Water actually used per Min.	Horse Power.	
		Speed per Min.	Diam.	Brdth	Dpth. of Bcket	Head.	Sluice open.		Nominal.	Effective.
	Ft. In	Feet	Ft In	Ft. In	Ins.	Ft. In.	Ins	C. Ft.		
Dartford, Saw	5 0	556.1	16 0	4 6	15	2 9	..	3,000	12.	
Ousburn, Oil..................	15 6	270.5	14 0	2 6	9	1 6	4	194.4	5.73	
Balbirnie, Water..............	19 6	432.2	22 0	4 0	10	..	..	257.0	9.78	6.07
Ficket, Paper	6 5	400.0	13 6	3 7	10	1 5	9	1290	15.73	
Tamworth, do., 1785......	5 6	515.3	15 0	3 0	16	..	14.5	2444	23.23	6.86
Elford, do.	4 9?	543.1	14 0	3 9	14	4 7	10.5	2199	24.7?	5.50
West Bromwich, Forge*	10 0	1082.3	14 0	2 10	12	6 8½	7	1341	25.48	8.9
Bromwich, Slitting.........	..	826.5	18 0	4 4½	9	2 4	3	430	..	
Hunslet, do.	8 2	810.5	12 0	3 10	15½	5 1	28	93	10.48	
Isleworth, Flour †	11 6	361.2	19 4	6 0	12?	0 8½	..	58		

* Hammer 7 Cwt., 106 blows per min., 20″ high. † 12.74 lbs. ground per min.

VALUE OF STEAM POWER.—Table 8,

Is taken from Weale's edition of *Tredgold*, and contains a useful *resumé* of the requirements of a steam engine; as applied in the best way, more economical results are now exhibited in the power developed for the coal consumed. The table is in fact the old Boulton and Watt standard, and only to be used as such when comparison with other forms of nominal horse power are required.

In Manchester, steam power for manufacturing purposes is charged at £25 to £30 per horse power per annum, including the rental of the room. About twelve looms are considered equal to a horse power; and, for ordinary weaving 45 to 50 shillings per loom is charged, including sufficient room for receiving goods and making them ready for market.

For drainage and town supplies, the Cornish engine, working with high steam, great expansion and slow combustion, is highly economical; 70,000,000 lbs. raised 1 foot high with a bushel of coals, or 94 lbs., is an effect that can be obtained for long periods with very trifling repairs or stoppages. The duty of these engines, where employed in pumping water in the metropolis, is, for a 90-inch cylinder, about 500 cubic feet per minute, against 150 feet head, burning five cwt. of coals per hour. See also page 36, for cost of pumping at Liverpool.

At the West Middlesex works, two 70-horse engines drive 390 cubic feet per minute into Kensington Reservoir, against 122 feet of head.

The table is headed with the quantity of water required for feed and condensation, per horse power, of condensing steam-engines; the actual quantity of water used will of course depend upon the area of cooling pond.

PRESSURE OF MERCURY & WATER—Table 9,

WEIGHT & STRENGTH OF PIPES—Table 10,

Are sufficiently explained therein: in the latter table is given the safe head of water which can be borne by pipes of the several dimensions. It will be seen, that in smaller pipes the limit of thinness of metal is not strength, but the practicability of making a good casting, and its after durability. In large pipes, strength of metal should be thrown into the ends, especially the upper or socket end.

FLOOD DISCHARGES—Table 11,

Gives the quantity of water, in cubic feet per minute, which would run off the ground, assuming that the several depths of rain, specified at the head of each column, were to be discharged in twenty-four hours. The first table contains the quantities necessary to be provided for 1 to 100 acres, in farm drainage and in sewage of towns, where, under favourable circumstances, rain will occasionally discharge an enormous amount over small areas. For instance, during the thunder-storm of August 1, 1846, there fell over a great part of London from three to four inches of rain in a much less time than three hours; nearly the whole of this must have found its way at once into the sewers.

The second table contains the discharge for 1 to 10 square miles, from one thirty-second of an inch up to 1 inch of rain in twenty-four hours. In the numerous cases where an engineer is called upon to discuss the amount of water that he may expect over a given area, either for the purposes of town supplies, for estimating the scouring effect of floods, or for ascertaining the size required for new drains, or improvement of river-channels, this table will give a key to the problem to be solved, if used with a due experience of the observed quantities which districts have been known to produce, as compared with the amount collected in rain gauges. It is, unfortunately, not in our power to collect many of these *data*, well-founded enough to ground a perfect theory, or embracing considerations sufficient for generalization; the application of examples must also be taken with due caution, because the quantity running away will vary according to the general slope of the country, and the geological nature of the rocks of which it is composed. Years of the same actual depth of rain in the gauge likewise vary in their stream-producing powers; one season is hot and dry, with heavy thunder showers; another is moist, with rain coming down frequently in small falls, supplying more for evaporation and less for streams.

ESTIMATE OF FLOODS.

In a paper by Mr. Mulvany, one of the Irish Commissioners of Drainage, are the following facts as to floods in the Shannon, which we have put into form, shewing the fractions of an inch of rain, distributed over very large drainage areas :—

Lough Allen is a reservoir of . . . 8,852 acres.
Drainage area being . . . . . . 146 square miles.

Floods rise frequently	3 ins. in 24 hours	= .284 inches rain over the whole surface.	
Less frequently	4 „ „	= .379 „	„
And sometimes	6 „ „	= .568 „	„

Lough Derg, above Killaloe, is . . . . 30,313 acres.
Drainage area of Shannon, above Killaloe, being 3,611 sq. miles.
„ „ of the immediate basin of L. Derg 960 „

This Lough, before the improvements of the Shannon,

Rose frequently	3 ins. in 24 hours	= .148 inches rain over the whole surface,	
Less frequently	4 „ „	= .190 „	„
About once in each year	6 „ „	= .296 „	„
17th November, 1840	12 „ in less than 24 hrs	= .600 „	„

The register of the rise of this flood in Lough Derg, is as follows :—

	Gauge. ft.	in.
1840, November 13th, to	9	8
to the 16th, when rain began	9	9
17th,	10	9
18th,	11	1
19th,	11	3
20th,	11	4
21st,	11	4
22nd,	11	8
23rd,	11	9

By Captain Beechey's Admiralty survey, of 1849, it appeared that, on the 4th December, the Severn rose 4.60 feet at Newnham, and 7.32 feet at Diglis; the particulars of this flood, compared with summer low water, are given in the pages devoted to the "Tides of the Severn." The discharge of this flood below Gloucester was at the rate of 751,245 cubic feet per minute, or 193.12 cubic feet per minute per square mile, being 00.99 feet or $\frac{1}{8}$ of an inch nearly run off the surface in 24 hours,

on the drainage area of 3,890 square miles. The summer run of this river, from Captain Becchey's observations, is given at page 33, at 33,111 cubic feet per minute, or 8.49 cubic feet per minute per square mile.

In flat districts of England, without any very high ground, we have an experiment, made between the 21st and 23rd of May, 1849, on the River Nene, at Higham Ferrars. This place is intermediate between the water-shed and Peterborough, being distant about twenty-five miles from the water-shed all round the west and north sides.

The drainage area above Higham Bridge is 383 square miles. On the 20th of May about one inch of steady continuous rain fell, raising the stream from its ordinary run of about 5,000 cubic feet per minute, to a quantity averaging about 32,000 cubic feet per minute, lasting from the evening of the 20th to that of the 23rd, when the river, in the course of a very short time, relapsed into its usual state. Dividing this quantity over the drainage area, we shall find that there flowed off the ground about .156 or just three sixteenths of an inch—thus the proportion flowing off the ground was about one-sixth of the rain-fall; in this example it must be recollected that the weather was beginning to be warm, and the flooding of meadows along the valley would have absorbed at least three inches in depth, which would represent about 1-16th of an inch more of rain having come down into the valley. The floods on the Nene have frequently twice, and sometimes three or four times, this volume.

August 8th, 1846, a storm, giving 1.88 inches in the gauge at Glencorse produced for four hours a run of 24,180 cubic feet per minute; this amount from 3,820 acres, would be equal to .437 or nearly 7-16ths of an inch of rain on the surface in this short time; probably more than this came down, as the reservoir had to be filled before the flood passed over the weir used for gauging; this is an indication of the violence of the celebrated Lammas flood of this date, which washed down several of the bridges on the North British Railway, then recently opened.

Mr. Bateman records an experiment near Bolton, where on a drainage area of 5,400 acres, 5 inches was measured in the rain guage, having fallen during eight consecutive days previous to the 10th of June (the end of May having been very wet); the flow of water had passed off entirely by the 12th of the month, when a quantity of water was found to have fallen=4.625 inches over the drainage area. This flood is exceeded frequently by twice and three times the volume.

In table 15a we have given, from the Report on supply of water to Manchester, by S. C. Homersham, Esq., C.E., an average of the heavy rain of .4 inch and upwards in each twenty-four hours, from observations at Manchester and in the range of hills between that place and Sheffield; it appears that these falls are from 40 to 50 per cent. of the total rain-guage returns. He records the following facts:—" At Waterhouse Lock on the Macclesfield Canal, on the night of the 8th May, 1847, a depth of two inches of rain fell during twelve hours; and, in the same time, 1·8 inches fell at Coomb's reservoir. Dr. Dalton remarks, that on the 22nd April, 1792, at Kendal, 4.592 inches of rain fell in twenty-four hours. It is not an uncommon circumstance for ·3 inch of rain to fall in hilly districts, in one hour; this quantity was registered at Coomb's reservoir on the 5th April, 1847. In 1844, out of 33 inches which fell at Chapel-en-le-Frith, one half was registered in the short space of thirty days."

In our own notes we find that the heaviest day's rain in each year coincide at Glencorse and Gilmourton, although they are fifty miles apart on the East and West side of Scotland respectively; comparing other heavy days of rain at these places, we have the following examples to shew, (if proof be needed) that heavy falls of rain extend very uniformly over wide districts.

Inches of Rain in	1845—August.		1846—August.		1847—December.
Chiswick	.70—18&19	..	1.28—4&5	..	.34—18
Boston	.86—19&20	..	.83—4&5	..	.94—18 & 19
Newcastle	1.53—19&20	..	Not known	..	1.70—18
Applegarth, Dumfries..	None.	..	1.00—8	..	1.37—16
Gilmourton	.50—21&22	..	2.10—7&8	..	.59—18
Glencorse............	2.18—19&20	..	2.72—7&8	..	1.21—18 & 19
Orkney, Sandwich	.38—19&20	..	1.07–9, 10, &11		Not known.

FLOODS OF SMALL DISTRICTS.

Mr. Glynn considers that for draining fen districts more than ten horses power per 1,000 acres is seldom required, the water being lifted about ten feet. Two inches per month is about the maximum rain-fall requiring to be discharged ; assuming this quantity to be thrown at a rate of 500 cubic feet per minute, a ten-horse engine will perform the duty in about 232 hours.—(*Paper on Steam Drainage of the Fens.*)

Mr. Roe states that he measured and drained off to one outlet 82 acres of *meadow land*, and made observations on the flow for six months ; the greatest amount found to reach the drain from a fall of half an inch of rain in the hour, was three cubic feet per minute per acre at the period of greatest flow, which was generally from three-quarters to one hour after the heaviest rain.—(*Evidence.*)

Mr. Phillips thinks that sewers should be made large enough to carry one inch of rain per hour, *i.e.* 60 cubic feet per minute per acre ; this is the calculated quantity which ran in some London sewers in the thunder-storm of August 1st, 1846.—(*Evidence.*)

The flood levels given in this gentleman's evidence, generally indicate a discharge from thunder-storms of 25 to 35 cubic feet per minute from each acre of urban drainage; this is equal to 1.66 and 2.33 inches of rain in 4 hours.

DIVISION OF FLOOD WATERS FROM ORDINARY DISCHARGE.

While upon the subject of floods it will be interesting to quote the substance of a paper by James Leslie, Esq., of Edinburgh, Civil Engineer, read before the Institution of Civil Engineers in April, 1851, as follows :—

It is frequently a problem to ascertain by guaging the average flow of a stream during a part of the year, exclusive of flood-waters; it being difficult to assign any fixed time when a stream is and when it is not in a proper state for guaging, as it would require a knowledge of the very fact which it is wished to ascertain ; moreover, persons must be found frequently to guage for many months together, without discretion as to what should be excluded, and sometimes stated intervals are named in an Act of Parliament. Mr. Leslie therefore proposes the following method :—

First.—The guagings are all to be set down in a table, in the *order of their quantities*—the whole number of observations is to be divided into four equal parts, whereof the lowest fourth will be held to be *extreme droughts ;* and the highest *floods ;* the average of the middle half is to be ascertained, and all above that quantity of the original table is held to be flood water.

A new table is then to be construeted, in which all the guagings not exceeding the average of the middle half are put down at their actual

quantity; but all that are above the average are put down as equal to that average quantity; the mean of the whole of the new table is to be considered as a fair average of the water flowing in the stream, exclusive of floods. Mr. Leslie gives a table of a stream thus treated, which varied in its run from 1,902 to 59,861 cubic feet per minute. Average of the whole was 10,231 cubic feet per minute; the average of the middle half was 7,234 cubic feet per minute; and the average quantity, exclusive of floods, was 5,830 cubic feet per minute.

Mr. Leslie also suggests that his plan might be used by dividing the guagings into only three equal parts, which gives a rather smaller result, but makes no important difference; the above stream treated in this manner gives the average of the middle third 7,085 cubic feet per minute; and the quantity, exclusive of flood water, 5,758 cubic feet per minute. An example is also given of a small stream varying from .27 to 272.4 cubic feet per minute.

	Cubic feet per minute.
The entire average was	35.50
Average of middle half	18.51
„ „ third	17.90
Final average, excluding floods by middle half plan	13.65
„ „ „ by middle third plan	13.40

FLOW FROM LARGE DISTRICTS.—Table 12.

Estimate of Annual Discharge in relation to Rainfall.

The Rain Guage is a most useful instrument in the hands of an engineer, if used with due experience of the effects which its records are known to produce in similar districts; although the results may be occasionally not altogether synchronous, yet on examining the broad facts we shall not find anything at variance with the general laws which govern the collection of vapours and their deposit in rain. Districts may greatly vary in their general slope and geological character; graüwacke, granite, and the volcanic districts generally throw water in great rapidity, and are equally liable to great drought in summer time, unless they are capped by moss beds, which act as sponges not always the most pure; some of the newer rocks, on the other hand, such as the old and new red sandstones, have great power of storing water; the latter rocks from their flatness, generally holding it as indicated by the wells, which are always plentiful in this formation; the former, on the other hand, generally give out the purest spring water when occurring on mountain slopes, rising above the plains occupied by our numerous coal fields.

In the chalk districts this porous material absorbs a great portion of the rain that it receives, collecting it in great underground sheets represented by the numerously-interlaid flint beds, and pouring out almost rivers at places that have no indication of a feeder; so strongly is this marked, that the chalk districts may be always identified upon the Ordnance maps by the absence of streamlets on its surface, a characteristic likewise of some of the mountain limestones and oolites.

In this latter formation we lately had occasion to examine springs which, although most copious, could be scarcely recognised to have any area of drainage beyond them; the rock, having a very flat underlie, was fetching water far away from the outcrop, and pouring it out at a point not 40 feet below the summit level of the hills whence it proceeded.

These instances are familiar to all who have studied the water bearing properties of the hills of Great Britain; watching the progress of agriculture and drainage, we find the hill pastures scored in all directions with sheep drains, while in agricultural districts thorough draining steadily advances; all these operations are rapidly contributing to pour out floods on the dwellers in the plains, the inhabitants of the rich levels at the mouth, or on the lower course of our rivers, who, by this simple but incontrovertible order of events, find themselves forced into improvement, which the natural resources of their soil had too long delayed. Frequently in this state of affairs, the march of improvement has commenced in the harbour at the mouth, and tidal volume is sent up vastly higher and sooner than known before; dredging machines are set to work, and bold piers or long river walls are constructed; and although the landowner may find his outfall better, he also discovers that a concurrent high tide and upland flood has topped the walls and robbed his meadows of their burthen, or swept down his ripening corn.

In the estimate of floods, at pages 26–9, we have endeavoured to sketch out a few examples, with which the engineer should expect to deal, in constructing outfalls, or improving lowland rivers. In the following table we give a few examples of actual discharge from considerable districts, where the total flow of water has been guaged for the whole year round. The Bann Reservoirs, and some of those near Manchester, are from Mr. Bateman's paper in the *Philosophical Memoirs* of that town.

TABLE OF ACTUAL DISCHARGE FROM LARGE DISTRICTS,

with the amount given per square mile, the amount of water run off in depth over the surface, and the storage in reservoirs where existing or intended.

—	Height above Sea.	Drainage Area.	Total Discharge for the Year.	Discharge per Square Mile.	Representing Rain-fall per Annum.	Registered Rain-fall per Annum.	Reservoir Room per Square Mile.
	ft. ft.	sqre. miles.	cube ft. pr. min.	cube ft. pr. min.	ins.	ins.	cu. ft. in millns.
Bann Reservoirs, 1837-8, moorland	400 to 2,800	5.15	1092.6	210.2	48.0	72.0	..
Greenock, 1827-8, flat moor.	512 to 1,000	7.88	1416.6	197.7	41.0	60.0	38.0
Bute (*a*), 1826, low country.	...	7.80	819.0	105.0	23.9	45.4	...
Glencorse Pentland Hills (*b*)	734 to 1,600	6.00	600.0	100.0	22.3	37.0	7.66
Belmont, 1843, moorland ...	850 to 1,600	2.81	630.4	224.3	50.7	63.4	26.8
„ 1844 „ ...	...	...	412.8	146.4	33.3	50.0	...
„ 1845 „ ...	...	...	511.2	181.9	41.2	55.0	...
„ 1846 „ ...	...	...	411.3	146.3	33.2	49.8	...
Rivington Pike (*c*) 1847-8 ...	1,545	16.25	1752.0	107.8	24.25	55.5	29.6
Turton and Entwistle, 1836.	500 to 1,300	3.18	576.7	181.3	41.0	46.2	31.43
„ „ „ 1837.	...	...	548.2	172.3	39.0	48.2	...
Bolton Waterworks, moor...	800 to 1,600	.80	100.2	125.2	32.7	...	25.6
Sheffield, since enlarged ...	...	1.42	...	...	...	...	36.5
Ashton, 1844...	...	.59	40.7	65.5	15.5	40.0	21.0

(*a*) This year's rain was about 12 inches less than an average.

(*b*) Glencorse discharge is only the amount exclusive of floods; the reservoir supply totally failed in the drought of 1843; it is now in course of enlargement. The Glencorse drainage is generally precipitous.

(*c*) Rivington Pike Reservoirs are not yet made. The amount running down for two years was gauged. The country is moor, partly flat, and partly precipitous.

In 1846-7 the author conducted an experiment by accurately gauging for four months the water, flowing from 3,800 acres, into the Glencorse Reservoir, in the Pentland Hills, belonging to the Edinburgh Water Company, as follows:—

	Cubic Feet.		Inches.
1846, December.—Supply into Reservoir..	19,762,000	=fall of rain	1.43
„ „	Registered	ditto	1.02
1847, January.—Supply into Reservoir ..	14,524,200	=fall of rain	1.05
„ „	Registered	ditto	.750
„ February.—Supply into Reservoir ..	18,637,100	=fall of rain	1.34
„ „	Registered	ditto	1.56
„ March.—Supply into Reservoir ..	9,662,520	=fall of rain	.69
„ „	Registered	ditto	1.02

The total rain passing into the Reservoir being 4.53
Ditto registered in rain gauges at level of Reservoir being .. 4.35
„ „ „ on the Hills being 4.71

Again, in the Bonally district adjoining, but about 500 feet higher than Glencorse, we found the mean run of the streams to be 112 cubic feet per minute, or equal to a fall of rain over 879 acres of 4.55 inches, the registered fall being as before 4.71 inches.

As a contrast to the foregoing table, we now offer a second:—

TABLE OF ORDINARY SUMMER DISCHARGE

of various rivers, streams, and springs as uninfluenced by any immediate rain; with the drainage area, and amount run off the surface represented in depth of rain.

RIVERS.	Height above Sea. Valley. Hill.	Drainage Area.	Total Discharge.	Discharge per Square Mile.	Representing Rain-fall per Annum.	Total average Rain-fall per Annum.
	ft. ft.	sqre. miles.	cubic ft. pr. min	cubic ft. pr. min.	inches	inches
Thames at Staines—chalk, greensand, Oxford clay, oolites, &c....	40 to 700	3,086	40,000	12.98	2.93	24.5
Severn at Stonebench—silurian..	400 to 2,600	3,900	33,111	8.49	1.98	
Trent at its mouth—oolites and Oxford clay	100 to 600	3,921				
Loddon (Feb., 1850)—greensand	110 to 700	221.8	3,000	13.53	3.01	25.4
Nene, at Peterborough—oolites, Oxford clay, and lias	10 to 600	620.0	5,000	8.45	1.88	23.1
Mimram, at Panshanger—chalk...	200 to 500	29.2	1,500	51.4	11.58	26.6
Lee at Lee Bridge — chalk (*Rennie*, April, 1796)...............	30 to 600	570.0	8,880	15.58	3.53	
Wandle, below Carshalton—chalk	70 to 350	41.0	1,800	43.9	9.93	24.0
Medway, driest seasons (*Rennie*, 1787)—clay	..	481.5	2,209	4.59	1.04	
Ditto, ordinary Summer run (*Rennie*, 1787)........................	..	481.5	2,520	5.23	2.19	
Verulam, at Bushey Hall—chalk	150 to 500	120.8	1,800	14.9	3.37	
Gade, at Hunton Bridge—chalk...	150 to 500	69.5	2,500	36.2	8.19	
Plym, at Sheepstor—granite ...	800 to 1,500	7.6	500	71.4	15.10	45.0
Woodhead Tunnel—millstone grit	1,000	...	139	..	..	46.0
Glencorse Burn ... ... (*e*)	750 to 1,600	6.0	130	21.6	4.9	37.4
Crawley Spring—felspar and porphyry— Summer (*e*)	556 to 1,600	.6	54	90.0	20.2	
„ Winter (*e*)	„ „	.6	77	128.3	29.0	
Blacksprings—felspar—Sum. (*e*)	1,000 to 1,600	.1	30	300.0	70.0	(c)
„ „ Winter (*e*)	„ „	.1	40	400.0	92.0	(c)
Bavelaw—sandstone—Summer (*e*)	900 to 1,600	1.42	120	84.5	19.0	(c)
Colzium „ „ (*e*)	„ „	4.20	113	29.9	6.87	(c)

The examples here given have generally been corroborated by our own observations; the rain at the places marked (*c*) has not been kept, but that at Glencorse represents the rain for the lowest point of the district; the rain on the hills is much higher.

The Blacksprings indicate a drainage from a district far beyond the water shed; they occur at a protrusion of basalt; these springs and others marked (*e*) are from gaugings made at different periods, under the provisions of Acts of Parliament, for the protection of parties having water privileges.

The Wandle, Verulam, and Gade, all flowing out of the chalk towards the metropolis, are from Mr. Telford's gaugings made in 1833, a period which he terms "the driest season known for the last half-century;" but there is reason to believe that this was not the time of the minimum discharge.

The table gives the run of the several streams per square mile of drainage area, which is an excellent measure of their productiveness, and we have likewise reduced the amount (as supposed to run uniformly during the year, irrespective of floods) into the quantity distributed over the drainage area, as fed by rain; for example, the summer run of the Thames is equal to 12.98 cubic feet per minute for each square mile, and represents 2.93 inches of rain falling over its drainage area, while the summer run of the Mimram is 51.4 cubic feet per minute for each square mile, representing 11.58 inches of rain.

DISCHARGE OF SEWERS.

By gaugings of various Westminster Sewers, made in the summer of 1845, Mr. Hawkins reported that the mean summer discharge of the Westminster district, *urban and suburban*, was .277 of a cubic foot per minute per acre; the urban only was .876 of a cubic foot per minute per acre.

GENERAL REMARKS.

In generalizing on the discharge of districts in ordinary and flood time, the observer will be well aware, that there are seasons of drought when the most certain streams are seriously affected in their water-bearing properties; the table exhibits the very high power of the Pentland Hills, yet we have it on record that almost the whole of these sources were dried up in the summer of 1843; there appear to be, indeed, rare occasions when hill-country suffers more from drought than lower districts—the lake district of Cumberland was similarly affected at about the same time.

In hotter countries these facts are proverbial; in the great tertiary plains of central Spain, which are 1,200 feet and upwards above the sea, large rivers shrink into dry gravel beds, while at the same time the seaward face of the mountains which fringe the Bay of Biscay, are clothed with verdure caused by perpetual rains; this grand escarpment is broken up into the wildest and most precipitous glens, where the vapours rolling from the sea are caught and poured down with astonishing rapidity and volume. The character of this great condensation, as it were, is so marked that severe droughts are experienced on the inland side of the escarpment (5,000 to 7,000 above the sea) while within a very few miles rains are daily pouring down. These effects occur in a similar manner along the escarpment of the Bombay peninsula, where the rainfall is from 80 to 150 inches in the year, while it gradually recedes to 10 or 15 inches in the Deccan or dry country; the same is to be traced on the coast of Arracan, and in California on the West Coast of America. The rainfall of the Western Highlands is remarkable, likewise that of the Lake district, as shewn by Mr. Millar, of Whitehaven, in his papers published by the Royal Society, whence we have drawn for Table 15.

SUPPLY OF WELLS.

We are naturally led into this subject when treating of the quantity of water falling over the surface of the ground, for it is evident that the supply of wells depends upon the freedom with which rocks will permit the passage of water, and on the absence of free discharge at escarpments or lower valleys to which the strata may dip. Faults must of necessity drain away the water due to the strata which they intercept, the extent depending upon the nature of such faults and the free character of the rocks; as faults are generally numerous, it is evident that the supply of wells must vary, according to the accident of position and depth; but this rule is not without exception, for there are many districts where, with pervious beds laying in great depth on impervious rocks, water is always to be found at the point where it would naturally be deposited by gravity.

Mr. John Dickinson has kept for many years, at King's Langley, an ordinary rain gauge, united with one of Dalton's plan, arranged so as to catch the rain passing down three feet below the surface through the natural soil, which has been filled in after the placing of the gauge in its position. The following tables, extracted from Mr. Josiah Parkes's Essays, exhibit the mean of eight years of the rain caught in the ordinary rain-gauge, with the amount passing through three feet of soil, and its proportion of the whole; the comparisons are highly useful, and if done on a more extended scale, they would be valuable additions to science.

YEAR.	October to March.			April to September.			Total of each Year.		
	Rain.	Filtratn.	℔ Cent. filtered.	Rain.	Filtratn.	℔ Cent. filtered.	Rain.	Filtratn.	℔ Cent. filtered.
A.D.	Inches.	Inches.		Inches,	Inches.		Inches.	Inches.	
1836	18.80	15.55	82.7	12.20	2.10	17.3	31.0	17.65	56.9
1837	11.30	6.85	60.6	9.80	.10	1.0	21.10	6.95	32.9
1838	12.32	8.45	68.8	10.81	.12	1.2	23.13	8.57	37.0
1839	13.87	12.31	88.2	17.41	2.60	15.0	31.28	14.91	47.6
1840	11.76	8.19	69.6	9.68	0.00	0.0	21.44	8.19	38.2
1841	16.84	14.19	84.2	15.26	0.00	0.0	32.10	14.19	44.2
1842	14.28	10.46	73.2	12.15	1.30	10.7	26.43	11.76	44.4
1843	12.43	7.11	57.2	14.04	.99	7.1	26.47	8.10	36.0
Mean	13.95	10.39	74.5	12.67	0.90	7.1	26.61	11.29	42.4

The mean of each month for the above eight years, is:—

	Rain, Inches.	Filtration, Inches.	Per cent. Filtered.
January	1.84	1.30	70.7
February............	1.97	1.54	78.4
March	1.61	1.08	66.6
April	1.45	.30	21.0
May.................	1.85	.11	5.8
June................	2.21	.04	1.7
July................	2.28	.04	1.8
August..............	2.42	.03	1.4
September	2.64	.37	13.9
October	2.82	1.40	49.5
November	3.83	3.26	84.9
December	1.64	1.80	100.0

Mr. Parkes remarks, that on the 7th and 8th November, ·48 inch rain fell; and on the 9th, ·46 passed through to the filter gauge, and by an

experiment on inch draining tiles, 24 feet asunder and three feet deep, which appear to have carried off all in 12 hours, he concludes that they were equal to such a discharge, viz., half-an-inch in 12 hours.

Referring to our table of the ordinary summer run of streams, and to the amount of rain-fall per annum which such run will require, we may safely assume that the mean is certainly not more than ten cubic feet per minute per square mile, or (Table 12), somewhat more than two inches per annum. If we double this quantity for the average of the whole year, due to springs and ordinary rain, or say 4 inches, we shall be probably tolerably near the ordinary run of a river, taking summer and winter, *exclusive of floods, and assuming no very wet or high mountain districts.*

Now the average filtration, from April to September, of the above eight years, may be taken as nothing for all practical purposes; while, from October to March, we have an average of 10.39 inches filtered through, out of 13.95 inches total fall. Of this winter portion of 10.39, we must allow at least six inches for floods running away at the time of rain, and then we have only 4.39 inches left from supply of rivers and wells, which, assuming our estimate of four inches for that due to rivers, leaves only .39 of an inch for wells alone. It is certain that this small quantity would give all that we have as yet known of the draft of wells in all ordinary cases; for how notorious is it, that ordinary wells fail in summer time, and how few wells are there of a never-failing character, unless they have some substantial reason for that quality.

When we consider the enormous tendency to collect given to an area, by the preponderating gravitation from the surrounding strata, produced by pumping at a depth of 100 to 200 or 300 feet below the surface, the wonder should be, rather the small produce of wells generally, than an argument for the great supply from wells. Considering the exertions made to get water at Liverpool by wells, the results shewn at page xxxvii are small; and of the larger instances in London, given at page xxxvi, some are notoriously influenced by the high tide of the Thames.

Whether wells, if unduly worked, are not another form of taking water out of the adjacent rivers or the springs which supply them, is a point which is at all events open to question; and the evidence is certainly rather favourable to such a conclusion in chalk districts. In the recent case of Dickinson *v.* The Grand Junction Canal Company, where defendants sank a well near the summit level of the chalk stream, flowing towards the Coln, and pumped thence over the watershed line into the canal locking northwards, Lord Langdale referred the matter to Mr. Cubitt, President of the Institution of Civil Engineers, who advised that the Canal Company should divide the water pumped, sending half down towards the Coln, and the other half northwards. This decision was in fact admitting the doctrine; qualified in some degree by the proximity of the well to the watershed line.

Wells and springs, in character identical, are provisions for the wants of humanity, ordained by Providence, so that man shall have water in detail wherever he may require it, for his daily use; and in order that the supply may be pure, the chemist informs us that the carbonic acid in the soil constantly purifies the percolating water in the slow passage (filtration) downwards; thus returning the liquid pure from the manure and other impurities of the upper soil—from the animal and vegetable wonders of the microscope, children of light and air, that cannot exist below; so that the earth, synonymous with corruption, is also all-powerful in the production and support of new life, as described by a great apostle before chemistry was known. Wherever immense popula-

tions are gathered together, these conditions are interfered with so as to upset the ordinary economy of nature, and give rise to the complications which the engineer is called upon to adjust.

WELLS IN THE LONDON CLAY AND CHALK.

The chief supply to the wells of London is the bed of sand which lies on the chalk under the great bed of London and plastic clays; the nature of this bed renders the communication between different wells undoubted, and it is equally certain that all the large wells have constantly to be deepened, to enable them to keep up their supply.

Mr. Clutterbuck, (Mins. Inst. Civ. Engrs.) says, that the permanent depression between 1841 and 1848, has been 12 feet or 18 inches per annum, the progress being thus:—

Hendon Union Workhouse	6	feet	in 8 years.
Cricklewood	10	„	„
Kilburn	20	„	„
Zoological Gardens, Regent's Park	19	„	„
Hampstead Road	10	„	„

Mr. F. Braithwaite gives a table, of which the following is an abstract, shewing the effect of pumping from the sand springs under the blue clay at Coombe's Brewery, Long Acre:

DEPTH OF WATER BELOW GROUND.

	1838.	1841.	1844.	1847.	1849.
January ...	113.6	119.0	131.0	133.8	148.6
March......	116.0	121.6	135.6	133.1	152.6
June	113.0	124.0	137.0	139.1	158.0
September..	118.0	124.3	134.6	146.0	160.6
December..	117.0	124.6	135.6	140.0	155.9

At Greenwich the well ebbs and flows during each tide in the .... Land springs 2 feet. Sand „ 3 „

At Coombe's Brewery, additional borings in the chalk, 100, 200, and 300 feet deep, gave only 4 cubic feet per minute more water; the water of this well has lowered 60 feet and upwards in 25 years past.

At Meux's Brewery, 260 feet boring in chalk only gave 1·6 cubic feet per minute more water.

These examples are taken from various discussions in the Minutes of the Institution of Civil Engineers, and we must leave the reader to draw his own conclusions. From the same sources we give the following table of

WELLS IN LONDON AND THE NEIGHBOURHOOD.

	Depth below ground. feet.	Below T. H. Water. feet.	Depth in Chalk. feet.	Depth Bored. feet.	Amount of supply c. ft per minute.
Bushey Meadows, Watford	—	—	—	—	200.0
Hanwell	—	—	—	—	20.4
Hampstead Rd., (a) Aug. 1838	183	105	37	—	10.3
" March 1839	—	—	—	—	21.1
Trafalgar Square	400	—	100	—	65.0
Reid's—chalk exposed 1,600 sq. ft.	—	—	—	—	32.0
Greenwich Hospital	253	240	130	100	—
Woolwich	600	590	580	—	160.0
Booth's at Brentford (b)	415	—	—	100	13.0
Well at Gravesend, 1837	—	—	—	—	13.0

(a) Well, finished in February, 1838. Depth 183 feet; worked by a 20-horse engine, at a cost of £2 17s. for each 24 hours. Gross cost of well, engine and pumps, £12,422.
(b) Supply chiefly from Sand Spring.

WELLS IN THE NEW RED SANDSTONE.

In Mr. Stephenson's late Report on the supply of Water to Liverpool, he comes to the following general conclusions:—

That an abundance of water is stored up in the new red sandstone, and may be obtained by sinking shafts and driving tunnels about the level of low water.

That the sandstone is generally very pervious, admitting of deep wells drawing their supply from distances exceeding one mile; but its permeability is occasionally interfered with by faults or fissures filled with argillaceous matter, sometimes rendering them partially or wholly water-tight.

That neither by sinking, tunnelling or boring, can the yield of any well be very materially and permanently increased, except so far as the contributing area may be thereby enlarged.

That the contributing area to any given well is limited by the amount of friction experienced by the movement of the water through the fissures and pores of the sandstone.

That there is evidence to show, that the tendency of the river water inland is slightly preponderating over the pressure of the body of water in the sandstone towards the Mersey, the wells being generally sunk about 20 feet below low water mark.

That it might be a fair conclusion under existing circumstances, that the equilibrium would be very nearly adjusted, because the mass of the wells draw their supply from the sandstone at a level somewhere between high and low water mark, and the column of fresh water from the sandstone exerting its natural pressure, prevents any ingress from the fluctuating column of tidal water; but that the uniform pressure of the column of fresh water is interfered with by the great extent of pumping from the wells; the effect of this, in many cases, being to lower the surface line of water in the sandstone below the river surface, when a reverse action ensues, and the brackish water obtains a slight advantage.

That the various proposals for obtaining water, *by sinking at one point* in the immediate vicinity of Liverpool, will not produce the stipulated

quantity. That experience shews the necessity of deepening the wells in Liverpool, from time to time, from the great demand. That there is little or no probability of obtaining permanently more than about 1,000,000 or 1,200,000 gallons per day, from any one well, and this only when not interfered with by other deep wells.

That the most, if not the only feasible plan for making the water contained in the sandstone available for the general supply of Liverpool, is to sink a series of wells scattered over a large area of country lying to the East or North-East of the town.

The Report states that the net cost of working the deep wells at Liverpool is as follows:—

Name of Station.	Height Water Lifted.	Quantity Raised.	Total Cost per Ann. of Raising Water.			Cost per ann. of Raising 1,000,000 Gallons, or 160,513 c. feet.		
	Feet.	Cubic ft. per Minute.	£	s.	d.	£	s.	d.
Bootle	40	100.6	1445	3	3	4	7	8
Bush	123	29.1	716	3	5	7	10	1
Soho	123	51.7	833	17	1	4	18	9
Hotham Street .	110	24.7	603	4	8	7	9	4
Water Street ..	156	45.8	874	7	10	5	16	6
Windsor	210	71.1	949	0	3	4	1	6
Green Lane ..	185	112.2	920	2	7	2	10	1

The gross cost of raising 112 cubic feet per minute, or 1,000,000 gallons per diem at Green Lane and Windsor Wells, is—

For current expenses including superintendence	£1,100
Depreciation upon Engines and Machinery, Engine-houses and Cooling-pond, £11,200 at 2 per cent. ..	224
Total per annum..	£1,324

From which Mr. Stephenson estimates each new station, including Mains for delivery into the Distributing Reservoir, thus:—

Current expenses, including superintendence	£1,100
Depreciation upon Engines and Machinery, Engine-houses and Cooling-ponds, £12,000 at 2 per Cent.	240
Depreciation of Mains, £8,000 at ¼ per Cent.............	20
Interest on Capital, namely—£30,800 at 4½ per Cent.	1,386
Compensation to Landowners.................................	250
Total per annum for distributing 112 cubic feet per minute, exclusive of service pipes	£2,996

Mr. Stephenson suggests, that if Liverpool is to be supplied with Water from Wells, they should be, as above stated, scattered at wide distances over the area to the East of the town; he estimates that each new station and its mains to the Kensington Reservoirs would cost £28,000, and allowing one station for each 1,000,000 gallons supplied, and the same quantity for each of the two present stations, (which cost, exclusive of

capital, £2,648 per annum) he gives the following comparison of the Annual Cost of supplying Liverpool with Water from Wells and from Rivington Pike :—

To obtain				Gravitation. Rivington, including interest on Capital of £500,000.	Pumping. Wells, including interest on Capital.
Gal. per day.	C. ft. per min.			£	£
8,000,000 or	891.4	will Cost	per Annum	28,100	20,624
9,000,000 „	1,002.8	„	„	28,356	23,620
10,000,000 „	1,114.3	„	„	28,612	26,616
11,000,000 „	1,225.7	„	„	28,868	29,612
12,000,000 „	1,337.1	„	„	29,125	32,608
13,000,000 „	1,448.6	„	„	29,381	35,604

The following is a return delivered by W. C. Mylne, Esq., to the Metropolis Water Committee, on 31st July, 1851 :—

"Estimate of the difference in the expense of supplying water to the New River Head, by means of Gravitation or by Pumping.

By Gravitation.

Interest, at 5 per cent., on the capital reported to Parliament, in 1821, as expended for bringing the water from Chadwell and Amwell to London, viz., £472,170	£23,600	0	0
Annual expenses on the river	4,600	0	0
	£28,200	0	0

By Pumping.

Interest on capital, and annual expense of pumping the same quantity of water from the River Lee, at or below Tottenham, into the New River	£15,500	0	0
	£12,700	0	0

Note.—The New River is capable of bringing 30 per cent. more water, without any extra cost. This extra quantity, if pumped from or below Tottenham, would add 30 per cent. to the cost of pumping."

We must observe that the capitalized cost of the New River was an estimate only, and that it was laid out originally for a limited quantity; four times the amount of water, if it had been then wanted, could have been brought in at no greater original cost of construction. The quantity of water brought by the New River from the Lee at Hertford, according to the returns of the company, is about 1,300 cubic feet per minute.

EXPENDITURE OF WATER.—Table 13,

Is arranged to show readily the relation of cubic feet per minute with the same quantity in gallons, for a minute, day, and year of 365 days.

THE FOLLOWING TABLE gives the value of water per annum, at a penny per 1,000 gallons, from 1 to 50 cubic feet per minute, and from 1,000 to 500,000 gallons per diem; the year being taken at 313 working days.

Cubic feet per Minute.	Gallons per Diem.	Value per Annum, at 1*d.* per 1,000 Gals.	Gallons per Diem.	Cubic feet per Minute.	Value per Annum, at 1*d.* per 1,000 Gals.
		£ *s.* *d.*			£ *s.* *d.*
1	9,000	11 14 9	1,000	0.111	1 6 1
2	18,000	23 9 6	2,500	0.277	3 5 2½
3	27,000	35 4 3	5,000	0.555	6 10 5
4	36,000	46 19 0	10,000	1.111	13 0 10
5	45,000	58 13 9	50,000	5.555	65 4 2
10	90,000	117 7 6	100,000	11.111	130 8 4
50	450,000	586 17 6	500,000	55.555	652 1 8

WATER SUPPLY AND POPULATION,—Table 14,

Is arranged to give a ready measure of the quantity of water required to supply various amounts of population at different rates of consumption; with these are given the number of square miles of ground required according to different sources of supply, with the cubic contents of Reservoirs. These data are given to guide, rather than to lay down any rule upon the subject; we have found this form useful in judging of the capabilities of districts where there is absence of special data. In using this Table the information given at pages xxx. to xxxii. will be applicable.

RAIN TABLES 15 and 15 a.

As a guide for practical application to the circumstances of any especial case, we have constructed from authentic sources these Tables of Rainfall at 55 places.

Table 15 shows the fall of rain averaged over a stated number of years, with the maximum and minimum quantity for those periods. Each year is formed of three periods of four months each—commencing with November, December, January, and February, for the winter division; March, April, May, and June, for the Spring division; July, August, September, October, for the summer division; each year being made up of these periods, instead of the customary twelve months.

This plan of division is adopted because, for purposes of comparison, it gives the seasons in better arrangement than the ordinary division into months; for instance, a wet November and December are not unusually followed by a dry January and February, and *vice versa.* To expect, therefore, a small discharge in March because the fall of rain may be small in the two preceding months only, would be calculated to lead into error. Moreover, the amount of deduction for evaporation, and especially absorption, will arrange itself more systematically under these divisions.

The blanks for Greenwich, in Table 15, should be filled up as follows; the details given by R. W. Mylne, Esq., were received too late for insertion thereon.

Mean.				Maximum, 1841.				Minimum, 1840.			
WINTER	SPRING	SUMMER	TOTAL 12 mos.	WINTER	SPRING.	SUMMER	TOTAL 12 mos.	WINTER	SPRING	SUMMER	TOTAL 12 mos.
Ins. 7.50	Ins. 6.37	Ins. 10.10	Ins. 23.97	Ins. 9.5	Ins. 8.1	Ins. 15.8	Ins. 33.4	Ins. 6.3	Ins. 3.7	Ins. 6.6	Ins. 16.6

The average of 20 years, from 1830 to 1849, was as follows:—

SPRING.		SUMMER.		AUTUMN.		WINTER.		TOTAL.
4.15 ins.	...	5.55 ins.	...	7.75 ins.	...	5.55 ins.	...	23.09 ins.

	Inches.
The maximum of 20 years, in 1841	33.40
The minimum „ „ 1832	16.10
The minimum average of 5 years, viz., the years 1832–4–7–40–7	17.48

The years 1832, 1833, and 1834, gave only 16.1, 20.9, and 17.8 inches consecutively, or an average of 18.26 inches.

The mean from 1820 to 1829 was	25.67
„ „ 1830 „ 1839	22.23
„ „ 1840 „ 1849	23.96
Average from 1820 to 1849 was	23.95

The following is the Devonport rain-fall for 9½ years, 1840 to 1849, taken about 80 feet above high water:—

Mean.				Maximum, 1841.				Minimum, 1846.			
SPRING	SUMMER	AUTUMN	TOTAL 12 mos.	SPRING	SUMMER	AUTUMN	TOTAL 12 mos.	SPRING	SUMMER	AUTUMN	TOTAL 12 mos.
Ins. 12.81	Ins. 8.02	Ins. 10.51	Ins. 31.34	Ins. 14.91	Ins. 11.93	Ins. 17.43	Ins. 44.27	Ins. 11.43	Ins. 7.20	Ins. 8.50	Ins. 27.13

Table 15 a is constructed from good specimens of the hill and the low country of Great Britain.

Glencorse is a deep valley in the Pentland Hills, 10 miles from Edinburgh, where observations have been kept by the Water Company since 1830, at the level of their reservoir or the lowest point of the basin; the hills rise precipitously all round to heights of 1,200 to 1,600 feet above the sea, and are about twelve miles from the Firth of Forth.

Gilmourton is in a valley of flatter character, with hills rising to 1,600 feet, at two to five miles distance in the south and west direction from the gauge—the hills are twenty miles from Glasgow, and the same distance from the west coast of Scotland.

The Boston observations are well known to represent the steady character of weather of the low country of Eastern England.

In this Table the object has been to show, in juxtaposition, the amount of rain falling in quantities so heavy as to affect streams, and the total amount given by the rain-gauge during each month. The minimum quantity, taken as "heavy rain" falling in each twenty-four hours, is .3 inch. The average number of days in the months and years in which the rain per diem was this, or above, is also given in the Table.

It will be at once seen, by those familiar with the subject, that this mode of arrangement indicates an amount probably available for streams, not at all unlike the result of experiments.

GENERAL REMARKS ON RAIN, AND LOSS BY EVAPORATION.

In using the term *evaporation*, as applied to this great process which is always at work in nature, the engineer has only to deal with the resultant facts; it is quite clear that the amount actually passing off the ground in the state of vapour may even exceed that shown by the rain-gauge. As an instance, we have drawn up the following statement of evaporation from surface of water in a shallow vessel, as compared with the amount of rain received in an adjacent gauge. The observations were made by Mr. Luke Howard, at Plaistow, and are averaged from 1812 to 1815:—

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
RAIN	1.93	2.00	1.46	2.48	1.71	2.14	2.19	0.98	2.85	2.05	1.75	1.60
EVAP.	1.20	1.63	1.42	2.47	2.67	2.85	2.99	2.25	1.33	.49	.44	.39

	AVERAGE RAIN. inches.	EVAP. inches.
On adopting the former division of four months,		
we have for the WINTER PERIOD............	7.28	3.66
„ SPRING „	7.79	10.41
„ SUMMER „	8.08	70.6
Total Average for the Years being..................	23.15	21.13

The experiments of Bishop Watson on evaporation went to shew that, during the time of bright hot sun, when there had been no rain for a month, the evaporation from grass was at the rate of ·035 inch in 12 hrs.
Another experiment one day after a thunder-storm „ ·087 „ „

Looking at these results, we must come to the conclusion that the supply which is given from above for evaporation, &c., must be far beyond the susceptibility of any ordinary rain-gauge, and cannot therefore shew the amount of liquid, in all forms, which is deposited by night and day during the year. When therefore, we speak of a certain proportion of the amount recorded by the rain-gauge being lost, and the remaining passing off the ground, we state the result of experiments; without at all questioning that there must be a far greater quantity evaporated to be again supplied by dew and vegetable absorption. Unless there are these sources of supply, beyond the indication of the rain-gauge, it would be impossible to account for the enormous evaporation produced each day, for long succession, in tropical countries, where dew has the effect of rain in early morning, and the year passes round with only a few thunder-showers, as in Egypt and part of the West Coast of America.

The author of the article *Physical Geography*, in the work of the Society of Useful Knowledge, has the following remarks upon this subject:

"Other things being equal, evaporation is the more abundant, the greater the warmth of the air *above* that of the evaporating body, and least of all when their temperature is the same. Neither does much take place whenever the atmosphere is more than fifteen degrees colder than the surface upon which it acts. Winds powerfully promote evaporation, because they bring the air into continual, as well as into closer and more violent contact with the surface acted upon; and also, in the case of liquids, increase, by the agitation which they occasion, the number of points of contact between the atmosphere and the liquid.

"In the temperate zone, with a mean temperature of 52½ degrees, the annual evaporation has been found to be between 36 and 37 inches. At Cumana, on the coast of South America (N. lat. 10½), with a mean temperature of 81.86 degrees, it was ascertained to be more than 100 inches in the course of the year; at Guadaloupe, in the West Indies, it has been observed to amount to 97 inches. The degree of evaporation very much depends upon the difference (greater or less) between the quantity of vapour which the surrounding air is able to contain, *when saturated*, and the quantity which it actually contains. M. Humboldt, from observations made in the passage across the Atlantic, found that in the torrid zone, the quantity of vapour contained in the air, is much nearer to the point of saturation than in the temperate zone. The evaporation within the tropics and in hot weather, is in temperate zones, on this account, less than might have been supposed from the increase of the temperature.

"The average yearly quantity of rain is greatest within the tropics; and it seems, in general, to diminish, the further we recede from the equator. In the torrid zone it amounts, at a medium, to 100 or 110 inches; while in the north temperate zone, it cannot be stated at more than 30 or 35 inches. These quantities are very differently distributed throughout the year in the two zones: the number of rainy days towards the equator is, in the majority of places, *less* than in the higher latitudes, and the rain consequently descends there in the most violent torrents: at Bombay, 16 inches have been collected in a guage in the space of twenty-four hours. In general, much more rain falls in mountainous countries than in plains, and in countries covered with extensive forests than in those where wood is less abundant. Annexed, is a table of the annual quantities which have been observed at several places.

Places.	Latitude.	Mean annual fall of rain.
Island of St. Domingo	19° N.	120 inches.
Ditto Grenada	12	112 „
Calcutta	12½	70 to 75
Rome	42	36 „
Paris	49	21 „
London	51½	23 or 24
Liverpool .. :	53½	34 „
Kendal, Westmoreland	54¼	60 „
St. Petersburgh	60	16 „
Upsal	60	26 „

"The average annual fall of rain at Bombay in the ten years 1817 to 1826, was 78.1 inches; of those years, the most rainy was in 1822, in the course of which nearly 113 inches fell: whereas in 1824, a season of extreme drought and famine, the supply did not much exceed 34 inches. At Arracan, in 1825, nearly 60 inches were registered in the month of July, and above 43 in August; from which we may conclude that the whole quantity within the year was at least 150 inches."

THE FOLLOWING IS A TABLE of the mean temperature of different latitudes, which will be useful in indicating the temperature of spring and other water, under ground.

MEAN TEMPERATURE AT DIFFERENT LATITUDES.

Stations.	Lat. N.	Temp.	Stations.	Lat. N.	Temp.
	D. M.	Fah.		D. M.	Fah.
Equator	0. 0	81. 50	London	51.30	50.74
Columbo	6. 58	80. 90	Dublin	53.21	48.65
Chandernagore	22. 52	75. 10	Kendal	54.17	47.58
Cairo	30. 02	70. 56	New Malton	54.10	47.53
Funchal	32. 37	68. 62	Copenhagen	55.41	45.95
Rome	41. 54	60. 66	Edinburgh	55.57	45.64
Montpelier	43. 36	59. 03	Carlscrona	56.16	45.46
Bourdeaux	44. 50	57. 82	Stockholm	59.20	41.57
Milan	45. 28	58. 28	Upsal	59.51	40.94
Nantes	47. 13	55. 35	Abo	60.27	40.28
Paris	48. 50	53. 65	Umeo	63.50	35.96
Brussels	50. 50	51. 47	Uleo	65.30	34.38

(See Article Mountain Barometer for further Tables of mean temperature.)

COMPARATIVE VELOCITIES, GRADIENTS, AND MEASURES—Tables 16, 17 and 18,

Are arranged for ordinary reference, as explained thereon. Table 18 has also the angle of various rates of slope, and the difference of length between the base and slope measures of each.

USEFUL WEIGHTS AND MEASURES. Tables 19 and 19a,

Contain a table showing the decimal proportions of a foot or unity, in reference to a duodecimal division or inches; likewise the decimals which represent the ordinary fractions of an inch (or any other measure) from one-sixteenth to fifteen-sixteenths; thus, four inches and eleven-sixteenths, or 4.6875 inches, is .390 of a foot. These conversions are useful in computations of all kinds. The table has several useful numbers, and the multipliers for converting the principal foreign measures into English.

Table 19a contains areas of segments of a circle, and lengths of their arcs; height of apparent above true level, for rotundity of the earth; square yards in decimals of an acre; and the number of bricks taken in a given amount of work.

WEIGHT AND STRENGTH OF MATERIALS.— Tables 20 and 21,

Require no explanation beyond what will be found thereon. These Tables have been collated from the best authorities, but rocks and earths, &c., will necessarily be found somewhat variable.

SUSPENSION BRIDGES.—Table 22,

Gives the chief principles involved in catenary curves, and can be thus applied in all cases where the strength is required for suspended chains of any kind.

The strain in lbs. a rope will bear safely $=$ girt $^2 \times 200$
Do. cable " $=$ girt $^2 \times 120$

***Chain Cable.*—Take the safe strain at about 8 tons per square inch of the iron of which it is made—*i. e.* four tons for each side of the link.**

Of good chain, the proof weight should be 10 tons per square inch of each side of the link.

THE FOLLOWING IS A TABLE of the size and strength of Newall's wire rope.

Hemp Rope.		Wire Rope of Equivalent Strength.			
Circumference.	Weight per Fathom.	Circumference.	Weight per Fathom.	Breaking Strain.	Working Load.
Ins.	lbs.	Ins.	lbs.	Tons.	Cwt.
2¾	2	1	1	2	6
3¾	4	1⅝	2	4	12
4½	5	1⅞	3	6	18
5½	7	2⅛	4	8	24
6	9	2⅜	5	10	30
6½	10	2⅝	6	12	36
7	12	2⅞	7	14	42
7½	14	3⅛	8	16	48
8	16	3⅜	9	18	54
8½	18	3½	10	20	60
9½	22	3¾	12	24	72
10	26	4	15	28	48
11	30	4⅜	16	32	96

ROOFS AND LOCK GATES.—Table 22a,

Contains the tension of the tie-bar of roofs or trusses, at several angles; giving the proportion of tension when the weight is unity. Also, the strain on three feet depth of surface of a lock gate in tons, and the size of oak timber necessary to bear three times the strain at different lengths of gate. This is from a paper by P. W. Barlow, Esq., C.E., in the first volume of the *Transactions of the Institution of Civil Engineers.* The strain is taken for gates placed at an angle of 19°.25′ with the square, which he shows to be the angle of greatest strength, taking all thrusts into consideration.

CAST IRON BEAMS.—Table 23,

Gives the safe load to be borne by beams having the specified dimension of bottom flange. This is constructed on Professor Hodgkinson's rule.

1. Multiply the area of the bottom flange by the depth of the beam, and divide the product by the length between supports (all in inches); the quotient multiplied by 514 will give the breaking weight at the centre.*

2. When a beam is uniformly loaded and supported at both ends, it will bear double the first result.

3. When a beam is fixed at one end and uniformly loaded, it will bear the same as the first result.

4. When a beam is fixed at one end and loaded at the other, it will bear only half the first result.

In the tables we have taken the safe load at one third of the breaking weight; but for railway girders it should not exceed one sixth, or half the tabular numbers. For safe deflection, a rough rule is—allow one fortieth of an inch for each foot of span.

In ordinary wrought iron beams, we have found that the first rule is very fairly applicable, using a constant of 1,500 for the breaking weight. In general use, a beam of wrought iron should not be strained beyond one-third of its ultimate strength, but it has the advantage of being able to bear on an emergency two-thirds, without any serious damage; whereas this would be imminent risk with cast iron, especially with moving weight; hence the superiority of wrought iron, for floors where motion is likely to be freely communicated.

In long cast-iron beams, a proportion of six area of bottom flange to one area of the top flange will not give sufficient stiffness to the latter; with a wide bottom flange it is also necessary to have angle stays to secure it to the central web, and to insure continuity of strain through the vertical direction.

The depth of a beam may decrease at any point towards the extremities in the proportion of the multiples of the segments of its length; thus, if a beam is 12 inches deep at the middle, and it is twenty feet in length, then at five feet from each bearing, the depth should be as $10 \times 10 : 15 \times 5 :: 12 : 9$ inches = required depth; but surplus strength and a thorough bed at the point of support are indispensable for security.

MARINE SURVEYING.—Table 24,

Contains various Tables useful for the nautical branch of the profession, especially in the use, for engineering purposes, of charts, which are generally constructed on astronomical measurement. The tide table is for computing rise or fall by time from high or low water; the surveyor on the British coast will find the Admiralty Tide Tables to be his best guide; their usefulness is being extended every year. The Tide Tables at the end of this volume give similar information for 1852-3-4, with the basis for calculating any other year by the use of the nautical almanac; the tables will thus be found useful in examining and comparing observations in past years, when occasion may require a comparison.

* This rule is somewhat empirical, but it has the advantage of being below the mark.

THE FOLLOWING TABLE gives the variation of the compass for different latitudes and longitudes, for which we are indebted to Raper's Tables.

APPROXIMATE VARIATION OF THE COMPASS.

Lat. Deg.	W.	Longitude—East.											
	10	0	10	20	30	40	50	60	70	80	90	100	110
	W.	W.	W.	W.	W.	W.	W.	E.	E.	E.	E.	E.	E.
35	22	19	17	14	10	7	3	1	5	5	4	3	1
38	22	20	18	15	10	7	2	1	5	6	4	3	1
40	23	21	18	14	10	7	1	1	5	6	5	3	1
42	24	21	18	14	8	7	1	2	5	6	5	3	1
44	25	21	19	14	8	6	0	2	5	6	5	3	1
46	26	22	19	13	8	6	1E	3	5	7	5	3	1
48	27	22	19	13	8	5	1	3	5	7	5	3	1
50	27	23	20	12	8	5	1	4	6	7	6	3	1
52	28	24	20	12	8	5	2	4	6	7	6	3	1
54	29	24	20	12	8	4	2	5	6	8	7	4	1
56	30	25	20	13	8	4	2	5	7	8	7	4	1
58	31	25	20	13	8	4	2	5	7	8	7	4	2
60	32	26	19	13	8	3	3	5	8	8	8	5	2
62	34	27	19	13	8	3	2	5	8	9	8	5	3

MOUNTAIN BAROMETER.—Table 25.

This is a very useful instrument, when properly managed, for surveys and other geodesic operations, which occasionally have to be made in districts, where even the level and theodolite is useless, until some idea of the line of country is sketched out. In finding the relative summit levels of different gaps or passes in a mountainous country, we have used it with great advantage over ground which, in fact, was inaccessible to ordinary instruments, which must be used step by step.

For finding the height in feet, subtract the logarithm of the upper station from that of the lower; multiply by six, and remove the decimal point four places to the right; the result is the elevation in English feet, generally sufficiently accurate for all purposes to which a mountain barometer should be applied. If perfect accuracy be required in a fixed instrument, we have to correct the mercurial column, when the scale is of brass, by deducting the fraction, opposite the temperature (in degrees Fahrenheit) of the instrument, from the observations.

First, for the Mountain Barometer, we have the correction in Table b, *deducting*, if upper station be coldest, the amount opposite the difference of temperature of the attached thermometers in degrees centigrade; or *adding* the amount if the upper station be the warmest.

Secondly, for the expansion of the air take the first correction and shift its decimal point three places to the left, and multiply it by twice the sum of the detached thermometer expressed in degrees centigrade; the product to be deducted or added as before.

Thirdly, for gravity the correction is to be added, as taken from Table C, according to the latitude and approximate height.

When an instrument having a cistern is used, we have the correction for capillarity in Table F, to be added to each observation before calculation; when a syphon barometer is used, we have no necessity for this correction.

Lastly, if fine and scientific observations are required, and accuracy is aimed at in hot weather and tropical countries, the observer should always have a portable dry and wet bulb thermometer; by this the original observations can be reduced to what they would be if the air at each station were perfectly dry. This is done by the rule in Table E, whence being obtained the temperature of the dew point, we can obtain the fraction to be deducted from the observation by Table D.

Example—Station A reads by Barometer 30.453 = 1.482950
„ B „ „ 29.341 = 1.466928

.016022

Then .01602 × 6 = .09612 and shifting the decimal point four places to the right the height of B above A is given = 961.2 feet.

But we will suppose that the temperature of the instrument at A is 27 cent.
„ „ „ „ B is 13 „

difference = 14 deg.

The temperature of the air being at A .... 25 „
14 „

The correction in Table B for 14 degrees is 67.58; for the expansion of air, by the rule we have .06758 to be multiplied by the double sum of the detached thermometers, or .06758 × 78 = 5.27 feet.

alt. correction = 67.58 „

72.75 „
less.............. 961.20 „
and adding for gravity... 2.80 „

corrected height .... 891.25 feet

If corrections for the aqueous vapour should be required, we will assume that at station A the dry bulb is 77 Fah.

wet bulb is 68 = diff. 9 deg. × 1.7 = 15.3 — 77 = 61.7 degrees for the dew point.

at station B the dry bulb is 57
wet bulb is 53 = diff. 4 deg. × 1.9 = 7.6 — 57 = 49.4 degrees for the dew point.

The correction then for these observations is thus:—

Station A Bar. reads	30.453
Less elastic force for 61.7 from Table D	.551
	29.902
Station B Bar. reads	29.341
force for 49.4 from Table D......	.361
	28.980

We have then the true barometric heights which may be treated as given in the example .... } 29.902 for Station A. 28.980 for Station B.

PRACTICAL REMARKS.

There are many varieties of mountain barometers; there is the standard one which is only fit for observations at a fixed station, because the setting of a large floating surface of mercury to an index, renders the observations liable to index error. The closed-cistern barometer, commonly called Englefield's, has the disadvantage of requiring a correction for the filling of the cistern, and we have also found these instruments sluggish in their action. The lightest and most philosophical instrument is Gay Lussac's; it requires no correction for capillary attraction, and having only to be read by the difference of the two legs of the syphon, there is an equal chance of index error in both readings.

A great superiority of this instrument is, that a magazine can always be carried, containing a number of spare tubes; and on a breakage, a new one can be put into the frame, and the instrument rendered again fit for use in a few minutes.

The Mountain Barometer is always arranged to read to 1,000th part of an inch, but we have generally found that two successive readings cannot be taken nearer than the third part of this quantity; excepting perhaps in the Gay Lussac, which can be inverted and read frequently, and not vary more than .002 in the result. No one travelling now should be without an aneroid or manometer, which are very susceptible, and far less liable to fracture or disturbance by motion.

MEAN READINGS OF THE BAROMETER.

As computed from Greenwich Observations, by James Glaisher, F.R.S.

Four times daily the reading of the barometer is at its mean value; these times in the several months are as follows:—

			h. m.			h. m.			h. m.	
In January......	at midnight ...	at	8 0	a.m. ...	at	0 40	p.m. ...	and at	5 0	p.m.
„ February ...	„ midnight ...	„	8 2	„ ...	„	1 40	„ ...	„	6 20	„
„ March	„ midnight ...	„	7 35	„ ...	„	1 50	„ ...	„	6 0	„
„ April	„ 1h. 0m. a.m....	„	6 40	„ ...	„	1 40	„ ...	„	7 20	„
„ May	„ 1 0 „ ...	„	8 20	„ ...	„	1 0	„ ...	„	8 0	„
„ June	„ midnight ...	„	4 20	„ ...	„	1 40	„ ...	„	9 20	„
„ July	„ 1h. 0m. a.m....	„	6 25	„ ...	„	1 40	„ ...	„	8 45	„
„ August	„ 1 0 „ ...	„	7 0	„ ..	„	1 10	„ ...	„	7 35	„
„ September ..	„ 1 0 „ ...	„	7 30	„ ...	„	1 0	„ ...	„	7 0	„
„ October	„ 0 25 „ ...	„	7 50	„ ...	„	1 10	„ ...	„	5 0	„
„ November...	„ 1 40 „ ...	„	8 20	„ ...	„	11 40	a.m. ...	„	5 45	„
„ December...	„ 0 40 „ ...	„	7 40	„ ...	„	0 45	p.m. ...	„	6 5	„

That mean reading takes place with the greatest degree of steadiness which occurs between mid-day and 2 p.m.; the actual time varies however with the season.

MEAN READINGS OF THE THERMOMETER.

TABLE I., showing the corrections to be applied to the Monthly Mean reading of a thermometer (placed four feet above the soil, with its bulb freely exposed to the air, but in other respects protected from the influence of radiation and rain) at any hour, to deduce the true mean temperature of the air for the month from the observations taken at that hour.

Local mean time.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October	Nov.	Dec.
	°	°	°	°	°	°	°	°	°	°	°	°
Midnt.	+1.0	+1.6	+2.9	+4.8	+5.4	+6.2	+5.0	+5.1	+4.0	+2.9	+1.7	+0.9
1 a.m.	+0.9	+1.8	+3.0	+5.2	+6.0	+7.1	+5.5	+5.5	+4.5	+3.0	+1.8	+1.0
2	+1.2	+2.0	+3.3	+5.7	+6.4	+8.0	+6.0	+6.0	+5.5	+3.4	+2.0	+1.0
3	+1.3	+2.1	+3.6	+6.2	+6.7	+8.7	+6.4	+6.3	+6.4	+3.6	+2.0	+1.3
4	+1.6	+2.3	+3.9	+6.6	+6.7	+9.3	+6.6	+6.5	+6.6	+3.8	+2.1	+1.4
5	+1.8	+2.2	+4.0	+6.7	+6.3	+8.8	+6.2	+6.5	+6.2	+3.8	+2.0	+1.4
6	+1.9	+2.3	+3.9	+6.0	+4.8	+6.4	+4.5	+5.5	+5.3	+3.5	+1.9	+1.4
7	+1.9	+2.1	+3.6	+4.3	+2.6	+3.0	+2.5	+3.3	+4.0	+2.8	+1.7	+1.5
8	+1.5	+1.6	+2.5	+2.0	+0.5	0.0	0.0	+0.9	+2.1	+1.6	+1.0	+1.3
9	+1.0	+0.7	+0.2	—0.9	—2.0	—2.5	—2.0	—1.6	—0.4	0.0	+0.4	+0.9
10	+0.2	—0.5	—1.9	—3.2	—4.0	—4.5	—4.0	—3.5	—3.0	—2.0	—0.6	0.0
11	—1.3	—2.1	—3.5	—5.3	—5.5	—5.8	—5.4	—5.4	—5.0	—3.8	—2.0	—1.3
Noon.	—2.3	—3.2	—5.0	—6.8	—6.7	—7.3	—6.4	—6.5	—6.4	—5.1	—3.1	—2.1
1 p.m.	—2.9	—3.9	—5.8	—7.9	—7.5	—8.1	—6.7	—7.5	—7.1	—5.5	—3.5	—2.4
2	—3.0	—3.9	—5.8	—8.2	—7.7	—8.6	—6.7	—7.7	—7.1	—4.9	—3.6	—2.3
3	—2.5	—3.6	—5.5	—7.7	—7.3	—8.4	—6.5	—7.0	—6.6	—3.7	—3.0	—1.9
4	—1.9	—2.8	—4.5	—6.7	—6.1	—7.4	—5.8	—5.5	—5.5	—2.8	—2.1	—1.3
5	—1.1	—1.6	—3.3	—5.4	—4.8	—6.1	—4.9	—3.6	—4.2	—1.7	—1.2	—0.8
6	—0.6	—0.6	—1.8	—3.5	—3.0	—4.5	—3.5	—2.0	—2.5	—0.8	—0.4	—0.4
7	—0.3	+0.3	—0.4	—1.1	—1.0	—2.4	—1.5	—0.5	—0.6	0.0	+0.1	—0.1
8	+0.1	+0.6	+0.9	+0.7	+0.9	0.0	+0.3	+1.0	+1.0	+0.7	+0.6	+0.2
9	+0.4	+1.0	+1.7	+2.0	+2.3	+1.8	+1.9	+2.4	+1.8	+1.3	+1.0	+0.4
10	+0.6	+1.3	+2.3	+3.2	+3.5	+3.6	+3.3	+3.3	+2.7	+1.9	+1.3	+0.5
11	+0.7	+1.5	+2.6	+4.1	+4.5	+5.0	+4.2	+4.3	+3.4	+2.4	+1.5	+0.8

The numbers are degrees Fahrenheit, and are to be added or subtracted as denoted by the signs.

To get the mean temperature truly, observations should be taken several times in the day, and at such times the algebraical sum of the corrections is a minimum.

TABLE II., showing the corrections to be applied subtractively to the simple arithmetical mean of the maximum and minimum thermometers, to deduce from their readings the true temperature of the air.

	°		°
January	0.2	July	1.9
February	0.4	August	1.7
March	1.0	September	1.3
April	1.5	October	1.0
May	1.7	November	0.4
June	1.8	December	0.0

We have thus two easy methods of finding the true mean temperature; first, by taking observations several times a day, and applying corrections

to their means from Table I.; and, secondly, by taking the half of the maximum and minimum readings and correcting it by the numbers in Table II.

At all places the form of the diurnal variation is a single progression, having one ascending branch and one descending branch, the maximum occurring early in the afternoon, and the minimum occurring at about sunrise; but the amount of the difference of these extremes is variable, depending upon latitude, elevation, locality, and geological formation of the country.

If we compare the mean temperatures of places that differ considerably from each other in latitude, we shall find that the mean values are lower as we proceed north.

If we compare the mean temperatures of places having the same latitude, we shall find that the mean value of those situated at the higher level will be less than those at the lower level.

If we compare places having the same latitude, we shall find that the mean temperatures of those places situated inland will be higher in the summer months, and lower in the winter months, than those situated in the vicinity of the sea.

If we compare places differing only in their geological formations, we shall find that those places situated upon an arid, dry soil, will have a greater range of temperature than those situated upon a clayey, wet soil.

It is therefore possible that the corrections in Table I. may not be of universal application, but as the form of the curve described by the daily march is similar at all places, with the exception of being more or less bold, the turning points occurring at nearly the same local time, it is most probable that the amount of the correction applicable to any hour at any place, is the same part of the whole monthly mean daily range at that place, as the correction at Greenwich is of the monthly mean daily range at Greenwich.—*Excerpt Phil. Trans.* Part I, 1848.

Tables 26, 27, 27a, 28, 29, and 30,

Contain the area and circumference of circles; squares, cubes, square roots, cube roots, and reciprocals 1 to 100; squares, square roots, and cube roots, 101 to 1,100; logarithms of numbers 1 or 100 to 1,000: logarithmic sines and cosines, 0 to 90 degrees for each 10 minutes; and natural sines, tangents, &c. &c.

These Tables need no explanation here; they are inserted as collateral aid, in applying the tables to the various wants of the Engineer, as outlined in the foregoing pages; any further application of them will be obtainable from the ordinary works on the mathematical branches of the profession.

Tables 31, 31a, 31b, and 31c,

Contain short abstracts for finding the value of Annuities and Leases, with the present value of a Reversion in perpetuity, and the value of Annuities according to the Legacy Act; taken from Inwood's Tables, by permission of Mr. Weale, the publisher.

Tables 32, 32a, 32b, and 32c, 33, 34, and 35,

Contain the method of calculating the time and height of tides of all the principal British Ports. Complete explanation will be found at pages 78 and 79. Table 32c, gives the Admiralty form for computing the height of the tide, and any period before or after high water, which is useful both for computations and for reducing soundings in nautical surveys, always recollecting, however, that river tides have different times of rise and fall, as will be seen in the tables of tidal rivers.

GENERAL REMARKS ON TIDAL PHENOMENA.

We suppose the reader of our notes to be previously well acquainted with the chief theories and phenomena of the tides, and if he wishes to make himself master of the subject as far as theory can carry him, the most elaborate and invaluable treatise on Tides and Waves, by the learned Astronomer Royal, will afford all that can be desired of theoretical computation and practical deduction. We will not therefore attempt to follow this treatise in its detail, but, to shew the enormous practical effect of depth and freedom of motion in length of waves, we give the following Table of the velocity of free or solitary waves. (Treatise on Tides and Waves, pp. 291, 292).

Depth of Water in feet.	Length of Wave in feet.							
	1	10	100	1,000	10,000	100,000	1,000,000	10,000,000
	Corresponding velocity in feet per second.							
1	2.26	5.34	5.67	5.67	5.67	5.67	5.67	5.67
10	2.26	7.15	16.88	17.92	17.93	17.93	17.93	17.93
100	2.26	7.15	22.62	53.39	56.67	56.71	56.71	56.71
1,000	2.26	7.15	22.62	71.54	168.83	179.21	179.33	179.33
10,000	2.26	7.15	22.62	71.54	226.24	533.90	566.72	567.10
100,000	2.26	7.15	22.62	71.54	226.24	715.43	1688.3	1792.1

"From which it appears that—

"1st. When the length of wave is not greater than the depth of water the velocity depends (sensibly) only on its length, and is proportionate to the square root of its length.

"2nd. When the length of the wave is not less than one thousand times the depth of the water, the velocity of the wave depends (sensibly) only on the depth, and is proportionate to the square root of the depth. It is in fact the same as the velocity which a free body would acquire by falling from rest through a height equal to half the depth of water.

"3rd. For intermediate proportion of length of wave and depth of water, the velocity can only be got by the general equation.

"The wave originally produced by the action of the sun or moon, may be called the *Free Tide Wave*. The semi-diurnal tide wave is of this character, and may be taken to have a period of 12 hours 24 minutes; now by the foregoing table we see that a wave proceeding 10,000,000

feet, will travel with a velocity sensibly independent of its length; on this principle, therefore, is calculated the following

TABLE FOR THE SEMI-DIURNAL FREE TIDE WAVE.

Depth of Water, in feet.	Velocity of free tide wave per second, in feet.	Length of free tide wave, in miles.	Space described by free tide wave per hour, in miles.
1	5.67	47.94	3.86
4	11.34	95.89	7.73
10	17.93	151.62	12.28
20	25.36	214.42	17.29
40	35.87	303.24	24.45
60	43.93	371.38	29.95
80	50.72	428.88	34.58
100	56.71	479.46	38.66
200	80.20	678.05	54.68
400	113.42	958.91	77.33
600	138.91	1174.4	94.71
800	160.40	1356.1	109.36
1,000	179.33	1516.2	122.27
2,000	253.61	2144.2	172.92
3,000	310.62	2626.1	211.78
4,000	358.67	3032.4	244.55
5,000	401.00	3390.2	273.41
6,000	439.27	3713.8	299.50
7,000	474.47	4011.4	323.50
8,000	507.23	4288.3	345.84
9,000	538.00	4548.5	366.82
10,000	567.70	4794.6	386.66
20,000	802.00	6780.5	546.82
30,000	982.25	8304.4	669.71
40,000	1134.2	9589.1	773.32
50,000	1268.1	10721.	864.59
60,000	1389.1	11744.	947.11

"The diurnal and other tidal waves, so far as they are free, may be all considered as travelling with the same velocity, but the column of lengths of the wave must be doubled for the diurnal wave."

In addition, however, to the *free tide wave*, which is that originally produced by the sun and moon, but not affected by them in the velocity of its propagation, we have that which Professor Airy calls the *forced tide wave*, produced by the immediate action of the sun and moon, with its highest or lowest point always at a determinate distance in that place (in the supposed canal) at which the disturbing forces vanish.

The following contains the substance of the general results of the inquiries made by the Committee of the British Association, in 1837, in a report for which we are indebted to Mr. John Scott Russell, who claimed to have discovered the existence of a GREAT PRIMARY WAVE of fluid, differing in its origin, its phenomena, and its laws, from the undulatory and oscillatory waves. The report stated—

"2. That the velocity of this wave in channels of uniform depth is independent of the breadth of the fluid, and equal to the velocity acquired

by a heavy body falling freely by gravity through a height equal to half the depth of the fluid, reckoned from the top of the wave to the bottom of the channel.

"3. That the velocity of this primary wave is not affected by the velocity of impulse with which the wave has been originally generated, neither do its form or velocity appear to be derived in any way from the form of the generating body.

"4. This wave has been found to differ from every other species of wave in the motion which is given to the individual particles of the fluid through which the wave is propagated. By the transit of the wave the particles of the fluid are raised from their places, transferred forwards in the direction of the motion of the wave, and permanently deposited at rest in a new place at a considerable distance from their original position. There is no retrogradation, no oscillation; the motion is all in the same direction, and the extent of the transference is equal throughout the whole depth. Hence this wave may be descriptively designated THE GREAT PRIMARY WAVE OF TRANSLATION. The motion of translation commences when the anterior surface of the wave is vertically over a given series of particles, it increases in velocity until the crest of the wave has come to be vertically above them, and from this moment the motion of translation is retarded, and the particles are left in a condition of perfect rest, at the instant when the posterior surface of the wave has terminated its transit through the vertical plane in which they lie. This phenomenon has been verified up to depths of five feet.

"5. That the elementary form of the wave is cycloidal; when the height of the wave is small in proportion to its length, the curve is the prolate cycloid, and as the height of the wave increases the form approaches that of the common cycloid, becoming more and more cusped until at last it becomes exactly that of the common cycloid with a cusped summit; and if by any means the height be increased beyond this, the curve becomes the curtate cycloid, the summit assumes a form of unstable equilibrium, the summit totters, and falling over on one side forms a crested wave, or breaking surge.

The report stated

"That in the rectangular channel the velocity is that of gravity due to half the depth. In the sloping or triangular channel the velocity is that due to one-third of the greatest depth. In a parabolic channel the velocity is that due to three-eighths or three-tenths of the greatest depth, according as the channel is convex or concave; and finally that the velocity of the great primary wave of translation of a fluid is that due to gravity acting through a height equal to the depth of the centre of gravity of the transverse section of the channel below the surface of the fluid.

"7. The height of a wave may be indefinitely increased by propagation into a channel which becomes narrower in the form of a wedge, the increased height being nearly in the inverse ratio of the square root of the breadth.

"8. If waves be propagated in a channel whose depth diminishes uniformly, the waves will break when their height above the surface of the level fluid becomes equal to the depth at the bottom below the surface.

"9. The great waves of translation are reflected from surfaces at right angles to the direction of their motion without suffering any change but that of direction.

"10. The great primary waves of translation cross each other without change of any kind, in the same manner as the small oscillations produced on the surface of a pool by a falling stone.

"11. The WAVES OF THE SEA are not of the first order—they belong to the *second or oscillatory order* of waves—they are partial displacements

at the surface, which do not extend to considerable depths, and are therefore totally different in character from the great waves of translation, in which the motion of displacement of the particles is uniform to the greatest depth. The displacement of the particles of the fluid in the waves of the sea is greatest at the surface, and diminishes rapidly. There are generally on the surface of the sea, several coexistent classes of oscillations of varying direction and magnitude, which by their union give the surface an appearance of irregularity which does not exist in nature.

"12. When waves of the sea approach a shore, or come into shallow water, they become waves of translation, and obeying the laws already mentioned, always break when the depth of the water is not greater than their height above the level.

"17. A tidal bore is formed when the water is so shallow at low water that the first waves of flood tide move with a velocity so much less than that due to the succeeding part of the tidal wave, as to be overtaken by the subsequent waves, or wherever the tide rises so rapidly, and the water on the shore or in the river is so shallow that the height of the first wave of the tide is greater than the depth of the fluid at that place. Hence in deep water vessels are safe from the waves of rivers, which injure those on the shore.

"18. The identity of the tide wave, and of the great wave of translation, show the nature of certain variations in the establishment of ports situated on tidal rivers. Any change in the depth of the rivers produces a corresponding change on the interval between the moon's transit and the high water immediately succeeding. It appears from the observations in this report, that the mean time of high water has been rendered 37 minutes earlier than formerly by deepening a portion of about 12 miles in the channel of a tidal river, so that a tide wave which formerly travelled at the rate of 10 miles an hour, now travels at the rate of nearly 15 miles an hour.

"19. It also appears that a large wave or a wave of high water of spring tides travels faster than a wave of high water of neap tides, showing that there is a variation on the establishment, or on the interval between the moon's transit and the succeeding high water, due to the depth of the fluid at high water, and which should, of course, enter as an element into the calculation of tide tables for an inland port derived from those of a port on the sea shore. The variation of the interval will vary with the square root of mean depth of the channel at high water.

The report suggests that "these results give us principles, 1st, for the construction of canals; 2nd, for the navigation of canals; 3rd, for the improvement of tidal rivers; 4th, for the navigation of tidal rivers; 5th, for the improvement of tide tables.

"The following experiments were made for the purpose of determining whether the velocity of the so called great primary wave were not affected by the initial velocity given to the fluid at its generation by the moving body. The velocity of genesis, or of the vessel by whose displacement the elevation of fluid was produced, is given in miles per hour, and the time occupied by the wave in describing 700 feet is given in seconds.

	Velocity of genesis.	Space described by the wave.	Interval of time.
(1.)	5 miles an hour	700 feet	62. seconds
(2.)	3 "	700 "	61. "
(3.)	10 "	700 "	61. "
(4.)	7 "	700 "	62. "
(5.)	7 "	700 "	62. "
(6.)	4 "	700 "	61.5 "

"From this it is manifest that the velocity of the propagation of the wave does not vary with the velocity of its genesis.

"To determine whether the height of the wave produced any variation in its velocity, the following experiments were made:—

	Height of the wave above the level.	Space described.	Interval.
(7.)	6.0 inches	700 feet	61.50 seconds
(8.)	5.0 "	700 "	61.75 "
(9.)	3.5 "	700 "	62.50 "
(10.)	2.0 "	700 "	63.50 "

"It appears from these examples that, in a given reservoir of fluid, the higher wave moves more rapidly than the lower; and it was afterwards found that the increase in height was equivalent in its effect on the velocity to an equal addition to the depth of the fluid in the reservoir.

"To determine whether the depth of the fluid affected the velocity of the wave, the following experiments were made in the same channel filled to different depths:—

	Depth of fluid.	Space described.	Velocity of wave.
(11.)	5.6 feet	486. feet	9.594 miles an hour
(12.)	3.4 "	150. "	7.086 "

"The former of these observations is exclusive of the height of the wave, and adding six inches to the depth of the fluid in this case, the height of the wave being already added to the depth in (12.), we find that the velocities are nearly proportional to the square roots of the depths, and are nearly equal to the velocities that would be acquired by a heavy body in falling through heights equal to half the depth of the fluid.

'In the last case the channel was rectangular, and consequently the depth of the fluid was uniform across the whole depth of the channel; it was next of importance to ascertain what law held in those cases where the depth diminished towards the edges of the channel. For this purpose two channels were selected having the greatest depths in their middle, and diminishing towards the sides. The following are the results:—

	Greatest depth in the middle of the channel.	Space described.	Velocity of wave.
(13.)	5.5 feet	1000 feet	7.84 miles an hour
(14.)	4.0 "	820 "	6.09 "

"In these instances the diminished depth at the sides has diminished the velocity of the wave below that due to the greatest depth in a ratio in the first example nearly of 9·5 to 7·8, and in the second of 7· to 6·. See Experiments (11) and (12).

"The following three experiments are instructive as having been made on channels in which the maximum depth was nearly the same in all; but in (15) the depth remained constant to the side which was vertical, in (16) the sides had a slope of nearly 20°, and in (17) a slope of nearly 40°, so as to diminish the depth towards the sides.

	Maximum depth.	Form of channel.	Space described.	Velocity.
(15.)	5.6 feet	Rectangular	486 feet	9.59 miles
(16.)	5.5 "	Slope of 20°	2038 "	8.83 "
(17.)	5.5 "	Slope of 40°	1000 "	7.84 "

"From these it is manifest that the depth of the channel, while it modifies the depth of the fluid, affects the velocity of the wave. It was not found that the breadth of the channel produced any similar effect.

"The report contained some experiments made on the river Clyde. The stations extended from the Bromielaw to Port Glasgow.

		Diff. of level at H.W.		Diff. at L. W.	H. W. time.	
Station	I. Glasgow	10.1 inches.	Higher than at Port Glasgow.	33 inches.	83 mins.	Later than at Port Glasgow.
Station	II.	9.1 inches.		31 inches.	76 mins.	
Station	III. Clyde Bank	7.0 inches.		27 inches.	61 mins.	
Station	IV.	6.1 inches.		25 inches.	43 mins.	
Station	V. Bowling	5.2 inches.		12 inches.	24 mins.	
Station	VI.	2.2 inches.		5 inches.	6 mins.	
Station	VII. Port Glasg.	0.0 inches.		0 inches.	0 mins.	

"From a laborious discussion of the observations, it appeared that the wave of high water travelled

From	IX. to VIII.	in 6 min.	14 miles	80 miles an hour.
From	VIII. to VII.	in 9 min.	6 miles	
From	VII. to VI.	in 6 min.	3.75 miles	20 miles an hour.
From	VI. to V.	in 18 min.	4.25 miles	
From	V. to IV.	in 19 min.	2.5 miles	8.1 miles an hour.
From	IV. to III.	in 18 min.	2.5 miles	
From	III. to II.	in 15 min.	2.75 miles	15 miles an hour.
From	II. to I.	in 7 min.	2.75 miles	

"These results shew that in the deep water being between 40 and 60 fathoms, or between 240 and 360 feet deep, the wave travels at the enormous rate of 80 miles an hour; that on reaching water from 20 to 30 feet deep, the velocity is diminished to 20 miles an hour; and from V. to II. where the river is wide, shelving, and shallow, the velocity of the tide wave is retarded to 8 miles an hour; while on ascending further up, where the banks nearly upright, and the contracted width give an increase of mean depth, the velocity has a corresponding increase to 15 miles an hour.

"It appeared by the plans that the average depth of the river, from I. to III., was 15 feet. From III. to V. the river is wide and shallow, spreading over extensive banks, where there are not 2 feet of water, for which we may take a third part of the greatest as a mean depth, or about 5 feet. In the division from V. to VII., both depth and breadth increase very rapidly to about 35 and 37; taking 25 feet as the mean depth, we have

Velocities of the Tide-wave as observed.	Mean depth.	Velocity due to depth.
80 miles an hour.	240—360 feet.	60—80 miles.
20 miles an hour.	25 feet.	19.3 miles.
8.1 miles an hour.	5 feet.	8.6 miles.
15 miles an hour.	15 feet.	14.9 miles.

The remaining experiments have not much practical bearing upon the objects of this treatise; we have abstracted the essential parts of the Committee's Report to the British Association, as highly instructive to the practical engineer in dealing with tidal rivers and canals, especially in the experimental portions. Professor Airy regards the great primary wave as simply the solitary wave in its earliest and simplest condition, in which a particle is actually moved a certain distance by the wave, and then remains at rest in a new position; this wave, he observes, by mathematical reasoning, may travel without any force to maintain its motion

provided it be long in proportion to the depth of the fluid, and that its velocity be $\sqrt{g\frac{k}{2}}$ k being the depth, and g the force of gravity in feet per second.

As to ordinary waves Mr. Russell's experiments shew that a wave always breaks when its elevation above the general level becomes equal to the depth of water; this fact is strikingly evident in the breaking of surf; as the friction on the bottom shortens the wave in proportion to its depth, it topples over. In a similar manner the effect is produced when urged on by wind in open sea, until the height of the wave becomes greater than gravity will permit it to stand.

As an excellent and accurate example of tidal action in seas and estuaries, we give the following abstract from a paper in the "Philosophical Transactions" for 1847, being observations on the

TIDES OF THE IRISH SEA,

And upon the great similarity of Tidal Phenomena of the Irish and English Channels. By Captain F. W. Beechey, R.N., F.R.S.

"The observations have shewn that, notwithstanding the variety of times of high water throughout the channel, the turn of the stream is *simultaneous*; that the northern and southern streams in both channels commence and end in all parts (practically speaking) *at the same time*, and that time happens to correspond with the time of *high and low water* on the shore at *Morecambe Bay;* an estuary rendered remarkable as being the point where the opposite tides, coming round the extremities of Ireland, finally meet. So that it is necessary only to know the times of high and low water at Morecambe Bay to determine the hour when the stream of either tide will commence or terminate.

"The chart of curves or lines of *direction of the stream*, Plate II., will shew at once the effect of the tide upon a vessel, wherever she may be placed in the channel, and especially direct her where, with a beating wind, she will be benefited by standing in shore or otherwise; and taken in connection with the very valuable series of observations which were carried round Ireland by the Ordnance at the suggestion of Professor Airy, we are made acquainted with several curious facts: first, that whilst it is high water at one end of the channel, it is low water at the other; that the same stream makes both high and low water at the same time; that there are two spots in the channel, in one of which the stream runs with considerable velocity without the water either rising or falling, and in the other, that the water rises and falls from sixteen to twenty feet without having any visible horizontal motion of its surface; and that during the first half of the flowing, and last half of the ebbing tide-wave, the stream in the south channel runs in a contrary direction to the wave, and goes up an ascent of about one foot in 4½ miles.

"Plate II. shows the lines of direction of the stream with the rate of the tide at its greatest velocity on the day of syzygy, all being reduced to the same standard.

"An inspection of the Plate will show that the tide enters the Irish Sea by two channels; of which Carnsore Point and Pembroke are the limits of the southern one, and Rathlin and the Mull of Kintire the boundaries of the northern.

"The stream in the southern channel (as before stated) has been ascertained to move *simultaneously in one vast current throughout;* running six hours nearly each way, at an average rate of from two to three knots per hour at the height of the springs, increasing to four knots and upwards near the banks and at the pitch of the headlands; its *times of slack water* corresponding sufficiently near for all practical purposes, with *the times of high and low water for the day at Morecambe Bay*, or more correctly *at Fleetwood*, which is twelve minutes earlier than Liverpool.

"The *central portion* of the stream of *flood* or *ingoing stream*, runs nearly in a line from a point midway between the Tuskar and the Bishops, to one six miles due west of Holyhead; beyond which it begins to expand eastward and westward, but its main body preserves its direction straight forward for the Calf of Man, which it passes to the eastward with increased velocity as far as Langness Point, and then at a more moderate rate on towards Maughold Head. Here it is arrested by the flood or southern stream from the north channel coming round the Point of Ayre, and is first swayed round to the eastward by it, and then goes on with it at an easy rate direct for Morecambe Bay.

"The *outer portions* of the stream are necessarily deflected from the course of the great body of the water by the impediments of banks on the Irish side of the Channel, and by the tortuous form of the coast on the Welsh. The eastern portion passing Linney Head rushes with great rapidity between the Smalls, Grassholm, and Milford Haven, towards the Bishops, which it passes at a rate of between four and five knots; sets sharply round those rocks in an E.N.E. direction, right over the Bass bank, and into Cardigan Bay; makes the circuit of that bay; and sets out again towards Bardsey at the other extremity of it; then sweeping to the N. by W. past the island and through the sound, it gradually takes the course of the shore, round Caernarvon Bay, filling the Menai Strait as far as Bangor; but the stream still continuing outside towards the South Stack, which it rounds, setting towards the Skerries at a rate of upwards of four knots; and finally, turns sharply round those rocks for Liverpool and Morecambe Bay; completing in its way the high water in the Menai, and filling the Dee, Mersey, and Ribble.

"The *western* portion of the stream, after passing the Saltee, runs nearly in the direction of the Tuskar, sets sharply round it, and then takes a N.E. ½ N. direction, setting fair along the coast, but over the banks skirting the shore. Abreast of the Arklow is situated that remarkable spot in the Irish Channel, where *the tide neither rises nor falls.* The stream, notwithstanding, sweeps past it at the rate of four knots at the springs, and reaches the parallel of Wicklow Head. Here it encounters an extensive bank recently known; and whilst the outer portion takes the circuit of the bank, the inner sweeps over it, occasioning an overfall and strong rippling all round the edge, by which the bank may generally be discovered; beyond this point the streams unite and flow on towards Howth and Lambay, growing gradually weaker as they proceed, until they ultimately expend themselves in a large space of still water situated between the Isle of Man and Carlingford, where occurs the phenomenon of the water rising and falling without having any perceptible stream. This space of still water is marked by a bottom of blue mud.

"In the north channel the stream enters between the Mull of Kintire and Rathlin *simultaneously* with that passing the Tuskar into the southern channel, but flows in the contrary direction. It runs at the rate of three knots at the springs, increasing to five knots near the Mull, and to four near Torr Head on the opposite side of the channel. The eastern branch of this stream turns round the Mull towards Ailsa and the Clyde, a portion passing round Sanda up Kilbrannin Sound and Loch Fyne.

"The *main body* sweeps to S. by E., taking nearly the general direction of the channel, but pressing more heavily on the Wigtownshire coast; off which it has scooped out a remarkable ditch, upwards of twenty miles long by about a mile only in width, in which the depth is from 400 to 600 feet greater than that of the general level of the bottom about it. Near the Mull of Galloway the stream increases in velocity to five knots, the eastern portion turns sharply round the promontory towards the Solway, and splits off St. Bee's Head; one portion running up the Solway, and the other towards Morecambe Bay.

"The *central portion* from a midway between the Mull of Galloway and the Copeland Islands, presses on towards the northern half of the Isle of Man, and while one portion of it flows toward the Point of Ayre, the other makes for Contrary Head, and is there turned back at a right angle nearly to its early course. Passing Jurby it reunites with the other portion of the stream, and they jointly rush with a rapidity of from four to five knots round the Point of Ayre, and directly across all the banks lying off there, and catching up the stream from the south channel off Maughold Head, they hurry on together towards that great point of union, Morecambe Bay. This bay, the grand receptacle of the streams from both channels, is notorious for its huge banks of sand heaped up in terrible array against the mariner unacquainted with its locality, and also remarkable for a deep channel scoured out by the stream, and known as the Lune Deep, which, to the wary navigator, is the great hidden beacon of his safety, and serves him, alike in fog or in sunshine, as a guide to his position, and to a harbour of safety in case of need.

"We have now only to speak of the *western limit* of the stream, which we left off Torr Head running at a rate of four knots off the pitch of the point. Hence it strikes directly towards the Maidens, boiling over the Highlander and Russell rocks, and other reefs in the vicinity of that dangerous group; and takes the direction of the coast again from Muck Island to Black Head, at the entrance of the Lough of Belfast, which it fills.

"The portion of the stream which sets up the Lough splits again off Grey Point; one portion flowing up towards Garmoyle, while the other bends back along the shore of Bangor, Grimsport and Orlock, and blends with the general stream which has come on from the Maidens and Black-head, and passes with it through the sounds of the Copeland Islands. Hence it proceeds along the coast, brushes the South rock, and runs on towards St. John's Point; off which, the stream, like that coming from the southward, expends itself in a large space of still water, which remains undisturbed although pressed upon by streams from various quarters.

"Such is a general description of the streams in both channels which attend the *flowing of the water*, or which, for the purpose of distinction, we may designate the *ingoing stream.*

"The ebbing or *outgoing* streams do not materially differ from the reverse of these, except that in the southern channel they press rather more over towards the Irish coast.

"This is a general idea of the course of the streams throughout the Irish Sea, represented in Plate II.; but besides these there are (as usual) at all the points and headlands, when abrupt, counter streams or eddies beginning at about two hours after the offing stream, increasing with the strength of the tide, and occasioning races and overfalls at the places marked on the chart. In the direction of the offing stream there is as little variation of the current at the different hours of tide as will be met with in any sea of similar extent, and indeed it is only with the slackening of the tide that the variations occur, which happens from about forty

minutes before to about forty minutes after high or low water at Morecambe Bay.

During the time these observations on the stream were in progress, others were made upon the *rise* and *fall of the water* at several stations in the channel, and wherever practicable at places in the offing. By combining these observations with the range of tide on the coast of Ireland, published in Professor Whewell's admirable paper on the Tides in the 'Philosophical Transactions' for 1836, Part II., and with observations made by Captains Robinson, Denham, Frazer, Sherringham, Williams, &c., Captain Beechey constructed a chart of lines of equal range of tide, Plate I. in order that the seaman may ascertain by a simple inspection of the chart, wherever he may be placed in the channel, the amount of spring range to which he has to adapt his soundings. In this chart the lines denote the range of tide at the places over which they pass, on a day when a spring tide at Liverpool rises thirty feet.

"In the Irish Sea it was found that the place of the *water at the half-tide interval* did not correspond with that of a mark at *the half range of the wave*, but that it was always below it, showing that the upper half of the wave rose and fell more rapidly than the lower. It was also found that the curve of the Irish Sea tide did not correspond with that of the Bristol Channel tide; that neither followed the law of the sines to corresponding arcs of tidal intervals.

"In connection with the range of tide is that of the apparent mean elevation of the water. All the observations confirm the remark of Professor Airy (Phil. Trans. 1845, Part I. p. 31.), viz., that this mean level is higher at the springs than at the neaps. The mean place of the water, however, for an entire lunation, during the summer months at least, is tolerably constant, and affords a fair standard to which the reductions used in our nautical surveys may be referred in the event of the gauge being removed by which the observations were made; annexed is the result of observations made at Holyhead during nearly four entire years.

APPARENT MEAN PLACE OF THE WATER, AT HOLYHEAD.

Month.	1838.		1839.		1846.		1847.		Mean of Months.		
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	
January ...	11	3¼	10	6	....		10	7	10	9⅓	
February...	10	6½	10	3	....		9	10	10	2⅓	
March	10	1	10	2	....		10	4	10	2⅓	
April	10	1	9	10	....		9	11	9	11⅓	Summer months.
May.........	10	2	9	9	10	0½	9	11¾	9	11¾	
June........	....		10	1	10	4	9	11¾	10	1½	
July.........	10	1	10	1½	10	1¾	9	10¾	10	0¾	
August.....	10	6	9	10	10	1	9	10¾	10	0¾	
September.	10	4	10	7	11	1	10	3¼	10	6¾	
October ...	10	6¾	10	3⅓	10	8	10	10	10	7	
November .	10	7	10	2½	10	7¾	10	9¾	10	6¾	
December .	10	7	11	2	10	6	10	11	10	9½	
Mean of the year......	10	5	10	2¾	10	5½	10	3¼	10	3⅚	

"All the tides of the Irish Sea partake of the nature of river tides in having their ebb longer than their flood, except those of Tuskar and Holyhead, which are the reverse. The respective intervals are given in the order in which the places occur.

DURATION OF TIDE.

	Rising.			Falling.	
	h.	m.		h.	m.
Tuskar.............	6	27	..	6	8
Bardsey	5	24	..	6	52
Holyhead	6	18	..	6	0
Peel, Isle of Man	6	0	..	6	15
Ramsay, Isle of Man..	5	48	..	6	35
Fleetwood	5	46	..	6	39

"All these are the mean of many observations.

"The change at Holyhead is remarkable, and if we follow the durations up to Ramsay, we shall see that Peel also, an intermediate station, is affected. The cause of this may possibly be connected with the effort of the water to maintain its level; for in projecting the curve of the wave on paper, this peculiarity, in connection with the very short flood of Bardsey, has the effect of reducing the curve from what it would assume, were Holyhead similarly influenced with other places.

Captain Beechey proceeds to trace the course of the stream from Pembroke to the Land's End; to connect the tides of the Irish Sea with those of the Bristol and English Channels, and finally with those of the offing. His following observations will be explained by reference to Plates III. and IV., which shew the tidal streams in the English and Irish Channels respectively.

"It seemed evident that the water was influenced by forces acting in opposition nearly to each other, and that there was a tide in the offing whose streams of ebb and flood did not correspond with those of the channels. By applying this idea first to the English Channel, the observations responded to it; and carrying it to the offing of the Irish Sea, and considering that channel as comprising the Bristol Channel within its limits, as the English Channel does the Gulf of St. Malo, the idea was confirmed so far as the observations themselves extended. This offing stream appears to be of great extent, setting to the north and south along the coast of Biscay and the British Isles, running six hours nearly each way, and exercising an influence with more or less effect over all the waters of the channels and estuaries it passes in its progress, diverting their courses, and in some cases, when the streams oppose, wholly overpowering or reversing their direction. From the connection of the observations of the Irish Sea with those of the Bristol Channel, it is clear that the whole of the ebb or outgoing stream of the eastern half of the Irish Channel runs into the Bristol Channel, and forms the flood or ingoing tide of the northern half of that great estuary; and *vice versâ* the ebb or outgoing stream from the northern half of the Bristol Channel, forms the flood of the Irish Sea, each tide passing to and fro with great rapidity round St. Govan's Head. The centre and southern half of the Bristol Channel receive their waters from the offing and the English Channel, the coast stream bringing the waters up from the Land's End and the English Channel, as the stream on the northern half did those of the Irish Channel, and *vice versâ*.

"The great offing stream at the entrance of the English Channel extends its influence as far up as Cape La Hague, beyond which, owing perhaps to the sudden contraction which there occurs in the Channel, the stream suffers no interruption, but, as in the Irish Sea, passes up and down the Channel six hours nearly each way as far as a line joining Dungeness and Cape Grisnez, the apparent *virtual head* of the tidal channel. Here the influence of the North Sea stream begins to be felt, and here, as in the Irish Channel, again *the time of high and low water at*

the virtual head of the tide regulates the turn of the up and down stream along the whole channel as far as the contraction. Beyond this the offing stream being governed by its own high water, and that occurring at about six hours earlier than that of the head of the channel, the offing stream either butts against the returning streams from the channels, or withdrawing its water, solicits their streams and thus alters their course, making them for the most part set across the Channel in curves more or less bent as the spot is more or less removed from the offing; so that there seems to be but one hour's tide each way that passes clean down the Channel from Beachy Head to Scilly, and round the Land's End to Bristol. The outgoing stream from Beachy Head encounters the ingoing stream of the offing tide somewhere about the Start Point, and both are turned down into the great Gulf of St. Malo, which seems to receive the accumulated waters of these opposite tides.

"Whether or not this influx is instrumental in raising the water here to the extraordinary height of forty-seven feet perpendicular range at springs, or whether it be owing to its form and position as regards the advancing tide wave, is a problem; but it is a coincidence that cannot escape observation, that this spot, like the Bristol Channel, is the concentration of streams from opposite directions; that it has its waters raised to the same extraordinary elevation nearly to a foot, and that its time of high water is nearly the same.

"On the change of tide, this great bay, like the Bristol Channel, as it received so it returns its waters in opposite directions, the tide splitting somewhere between Alderney and the Start; but here especially, as also in a similar locality in the Irish Channel, we are in want of observations.

"In tracing these streams, it was impossible not to be impressed with the many coincidences which assimilate the tidal phenomena of the two channels, so much so as to render it probable that they are subjected to precisely the same laws.

"Considering the Irish Channel to extend from a line joining the Land's End and Cape Clear to the end of the tidal flow, which is either at Morecambe Bay or Peel, in the Isle of Man; and the English Channel as reaching from a line connecting Ushant with the Land's End, to the end of its tidal flow, or to Dungeness. We shall then see that the English Channel, from its outer limit to the end of its tidal stream, is 262 geographical miles, and that the Irish Channel, from its western limit to the end of its tidal stream, is nearly the same; being about 265 geographical miles. In both channels the stream enters from the south-west, and flows up until stopped by a counter stream. In both channels there is a contraction of the strait almost midway, by the promontories of Cape La Hague in one instance, and St. David's Head in the other, and at very nearly the same distances from the entrance. This contraction is, in both cases, the commencement of the regular stream, which flows six hours nearly each way, the *turn of the stream throughout coinciding with the times of high and low water at the virtual head of the channel*, situated in both cases about 145 miles above the contraction, and that time being very nearly the same, viz., 10h. 50m. at full and change; below this contraction, away from the land, the stream in both cases varies its direction nearly every hour, according to the force exerted upon it by the opposing offing stream.

"In both cases, between the contraction and the southern horn of the channel, there is situated a deep estuary, the Bristol Channel and the Bay of St. Malo, in which the times of high water coincide, and where, in both cases, the opposing streams meeting in the channel pour their waters into these gulfs, and where the tides in both places rise to the extraordinary elevation of forty-seven feet at the syzygies. From the

Land's End to the meeting of these streams in the Bristol Channel is sevénty-five miles, and from Brest to the meeting of the streams off Guernsey the same. A still further coincidence is apparent between the phenomena of these channels. In one, at a place called Courtown, a little above the contraction of the strait, and at 150 miles from Cape Clear (its entrance), there is scarcely any rise or fall of the water; and in the other channel (about Swanage), situated also a little above the contraction of the strait, and just 150 miles from the Land's End, there is only five feet rise of the water at a spring range. In both cases these points of small range of tide are situated on the opposite side of the channel to that of the high elevation above mentioned, and in both cases these spots are the node of the tide-wave (on either side of which the times of high and low water are reversed). And again we trace a similarity in an increased rise of the water on the south-east sides of both channels abreast of the virtual head of the tide: at Liverpool in one case, where the range amounts to thirty-two feet, and at Cayeux in the other, where it is thirty-four feet.'

"It may also be shown that the progress of the tide-wave along the side of the channels opposite the node is not very dissimilar. Reckoning in both cases from the line which we have before drawn, as the outer limits of the channel, we find that in the English Channel, from this line to Cherbourg, opposite the small range of tide,—

	Miles per hour.		Miles.
The wave travels	50	and if complete would be in extent	616
In the Irish Channel, from a similar line to Bardsey, it travels	52		649
From Cherbourg to Havre	32		397
From Bardsey to Holyhead	16		193
From Holyhead to end of tide	78		959
Dieppe to the end of the tide	75		922

These numbers are given roughly, merely for the purpose of showing the general resemblance in the character and motion of the wave; and it is probable a more judicious selection of positions and numbers would give a still nearer coincidence. Besides which we are somewhat uncertain as to the establishment at our starting-point. As a comparison, however, the numbers run fairly together. In both cases the retardation of the tide-wave about mid-channel, and the great elongation of the wave towards the end of the strait are remarkable, especially in the Irish Sea.

"Lastly, we may notice a singular coincidence in more respects than one, indeed, between the situation of the node placed by Professor Whewell in the North Sea, and a corresponding point of small range and inversion of tide at the back of Kintire. The node or hinge of the tide in the North Sea is curiously enough situated as nearly as possible at *the same distance from the head of the tide off Dungeness, as the node at or near Swanage* is on the opposite side of it; and the node at Kintire communicated by Captain Robinson, is about the same distance from the meeting of the tide in the Irish Sea as the North Sea node is from the meeting of the waters off Dungeness, and is similarly *situated with respect to the node of Courtown as the North Sea node is with regard to Swanage.*" The forthcoming part of the "*Philosophical Transactions*" will contain a most interesting extension of Captain Beechey's investigation on the tides of the English Channel. *(See Appendix.)*

We have given this example of the Irish Sea with Captain Beechey's remarks at great length, because it is a type of what we find practically and may expect from theory in the development of the simple tidal wave, and the numerous offshoots or minor vibrations, and the secondary efforts

produced by Mr. Airy's "forced tidal wave." These great vibrations follow the deepest and smoothest channels with their maximum velocity, and are retarded by laws which there is no doubt could be strictly defined, if we had the nature of bottom, and other disturbing forces, as elements in the calculation. It is evident that the primary, or great tidal wave, passes in at each end of the channels with the deepest line of sounding; this produces the alternate overflow and recession of the central volume towards the coasts, while the offing tide, which is described as apparently passing across the entrance of the channels, is nothing more than the same effect of a great succession of waves, following the disturbing or creative cause round the globe, and turning over towards the gradually shoaling of the bottom, approaching the British Isles, where again, the line of least resistance is taken up the channels, by the diverging waves. On reference to our remarks on the various rivers and estuaries of which we have given the phenomena from accurate experiments, we see precisely the same effects produced, although frequently developed to a greater degree by rapid diminution of width and depth, or *vice versâ*; and in tracing the action of both the hydrodynamic and the vibratory action of water, we must always recollect that it is a *non elastic* fluid; so that wherever at a point, in a given channel, there is want of area, we have increased head or oscillation, and as a secondary effect, increased velocity; while on the other hand, where there is cessation of velocity, we have increase of area. So, where the bed and banks are capable of being acted upon, (and what are not?) we find invariably that, unless perfection of regularity exists, there is perfect irregularity; that is to say, for every indentation there is projection—for every depth too great there is depth too little; for every variation *above* the mean, or true velocity, we have a similar falling *below* the mean; a perpetual recurring equilibrium which is attained by velocity or depth, by time or space.

Thus it is the great law of equilibrium which indicates what should be the proportion of artificial hydraulic construction; the more nature is aided in creating such equilibrium, the more rapidly are her powers developed; by deepening, and straightening, and reducing into train any channel or tidal river, we get nature to aid in producing the effect, calling in assistance of a tenfold effect, because it is one developing upon itself, and generating new powers from the combination.

We subjoin remarks from Airy's Treatise in reference to the cotidal lines of the globe, as they have especial relation to the question of depth and its effects.

"In all places where the circumstances of depth, &c., vary much in a small extent of sea, we may consider the alteration in the tides through that extent as following simply the laws of waves on which no force is acting, (because the length of the column of water on which the sun or moon acts is too small to allow their attraction sensibly to modify their pressures.) Suppose now that in the neighbourhood of any particular coast, the bottom shelves gradually from deep sea to one comparatively shallow. This would be attended, theoretically, with two consequences. The first is, that the wave would travel more slowly, and therefore the separation of the cotidal lines corresponding to successive hours would be less, or the cotidal lines would appear to be crowded together on the map. The second is, that the magnitude of the tides would be much increased. And these circumstances might be found in places where the change in the depth was not known from observation; for the usual limit of sounding is 200 fathoms, which is probably a small quantity compared with the depth of the ocean. We may then expect that, where the cotidal lines approach closely, the magnitude of the tides will be

increased. Now this does occur. A well-marked instance is the Bay of St. George, in South America, in which a close approximation of cotidal lines is accompanied with large tides. It is possible here that the tides may be still further increased by the converging form of the waves.

"Another curious effect of the same cause is the distortion of the lines produced by islands, surrounded by shoals, in the ocean. The shoals prevent the tide-wave from advancing rapidly, and the cotidal line is therefore thrown back; but, conceiving the ridge of the wave to be thus bent, it is easy to imagine that after passing the island the two lateral parts of the wave will bend round it till they unite, and will then form a straight front nearly as before coming to the island. The successive cotidal lines will have forms corresponding to the forms of the ridge of this wave at successive times. Of this there are several instances apparently beyond doubt. Thus the 1 o'clock line is thrown back by the Azores; the 11 o'clock line is bent by the Bermudas, and its lateral branches nearly meet; the 10 o'clock line, after having been interrupted, just meets behind New Zealand. A similar effect of the same cause is, the universal dragging of the wave along the shore.

"The velocity of the tide-wave ought, with the assistance of the table, to give us good information as to the depth of the sea. Thus in the North Sea, the tide-wave in 9 hours appears to describe somewhat less than 6 degrees of latitude, or, on the average about 45 miles per hour. This, by the table in page lii., corresponds to a depth of 140 feet. We believe that the average depth along the line of deep channel is greater than this, and that at the sides less; and it is probable that the actual velocity is effected by both these. If the tide-wave of the Atlantic were purely derivative, it might be considered as describing 90 degrees of latitude, from the southern 1 o'clock line to the northern 1 o'clock line, in 12 hours, or to move about 520 miles per hour; which would imply a depth of about 18,000 feet or 3½ miles. The reader will have no difficulty in extending similar remarks to other seas; in this, Plate V. will assist his inquiries.

In closing this part of our remarks we quote from Dr. Whewell's paper on the Tides, read to the Royal Society in December, 1847, relating chiefly to the tides of the Pacific and the diurnal inequality. He remarks that the cotidal lines in the observations of 1834 and 1835 shewed one feature, viz., their meeting the shore at a very acute angle, and following its flexures with an almost parallel course at a little distance, and that consequently the tide-wave which runs up the middle of a channel is very much in advance of its place at the sides; this is quite in harmony with the laws of fluids, and with the effect of friction and decrease of depth along shore.

ON THE DIURNAL INEQUALITY

Dr. Whewell remarks that it was noticed by Newton at Plymouth and Bristol, and has been commonly called the difference between the *day* and *night* tide, which is in fact only a temporary distinction.

"It depends upon the moon's declination, and changes to alternate tides when the moon's declination changes from north to south, and *vice versâ*. Its rule is expressed in the following form:—

For moon's N. declination { *Add* to the tide following moon's South transit,
Subtract from the tide following moon's N. transit,

For moon's S. declination { *Subtract* from the tide following moon's S. transit,
Add to the tide following moon's N. transit,

the quantity added or subtracted being greater as the declination is greater; and the declination being taken for one, two, or three days

previous to the tide. According to this law, the inequality has been introduced into the Tide Tables for Liverpool, Bristol, and Plymouth, as given at page 80 *et seq*.

"This rule of the diurnal tide may, *for some months*, produce the effect of making the afternoon tides greater than the morning tides, or *vice versâ*. Suppose the place to be one where the tide happens (in general terms) soon after the moon's (*south* or *superior*) transit; then, beginning from new moon, the afternoon tide for a fortnight follows the south transit of the moon. Supposing that during this fortnight the moon has north declination; then the diurnal inequality is additive by the rule, and therefore the afternoon tide is, during this fortnight, the highest. Now at the end of a fortnight of north declination, the declination changes to south. But at the end of a fortnight, the afternoon tide begins to be that which follows the *north* or *inferior* transit of the moon; and therefore again, by the second part of the rule, the inequality is still additive, and the afternoon tide is still the greater. And this will continue to be the case till the points of no lunar declination are shifted away from the syzygies by the motion of the moon's nodes relative to the sun. But if the declination pass from north to south, or the reverse, at a different period from that which transfers the afternoon tides from one transit to the opposite one, we shall no longer have this apparent constancy in the relation of morning and afternoon tides. If, for instance, the tide-hour being such as has already been supposed, the change of declination, north and south, takes place when the tide is at four, five, six, or seven o'clock; the afternoon tide will then (or rather one or two days later) change from being the greater to being the less, or *vice versâ*. Or if the tide-hour be six o'clock, the tide being (in general terms) six hours after the moon's transit, the afternoon tide will follow a south transit of the moon from the time when the moon is six hours west of the sun to the time when she is six hours east of him, and then change and follow a north transit; and so on alternately. Hence, if in this case the moon's ascending node be at six hours west from the sun, the declination will be north while the afternoon tide follows a south transit, and therefore the afternoon tide will be the greater for the whole lunation. But if, in this case, the node be in conjunction with the sun, the afternoon tide will change from smaller to larger, or the reverse, at the syzygy, that is, when the tide is at six o'clock; or rather, a day or two later.

"This last-mentioned circumstance, that the change in the features of the tides takes place a day or two, or perhaps longer, after the astronomical configuration by which it is determined, is common to all the empirical laws of the tides. It has recently been shown by Mr. Airy that this is a result which follows from supposing the tidal motions of the sea to be affected by friction. The amount of this retardation of the phenomena for each place, or, as we may term it, the 'age of the tide' relative to the diurnal inequality, is different for different places; and must, for each place, be learnt from observation;" as is shewn in our "Tide Tables for British Ports."

"The inequality of heights appears in the *zigzag* form of the line drawn through the summits of ordinates projected from the heights of successive tides. This zigzag structure is sometimes of a moderate degree of abruptness, as in the tides of the coast of North America, and of Portugal, and those of Plymouth, and sometimes extremely abrupt, as the heights of low water at Singapore. In this latter case, the diurnal inequality sometimes makes a difference of no less than *six feet* between the height of the morning and afternoon tide; the whole rise of the mean tide being only seven feet at springs, and the difference of mean spring and neap tides not more than two feet.

"While in some places it affects the heights, and at other places principally affects the times, for instance, the diurnal inequality which alters the low water four feet at Port Essington, and six feet at Singapore, affects the high water to a still greater extent in the Gulf of Cambay, and disturbs the times at the entrance of the Persian Gulf.

"It was remarked on the occasion of the observations of 1835, that the diurnal inequality on the coast of North America followed the changes of the moon's declination almost instantaneously; while on the coasts of Portugal, Spain, and France, the changes of lunar declination were represented in the diurnal inequality two or three days later; and at the Cape of Good Hope, about the same time." Dr. Whewell considers that this feature throws great difficulty in the conception of that motion of the waves by which the tides are produced, and suggests the necessity of some new mode of conceiving that motion. But we think the discrepancies are rather indicative of geographical and local difficulties *in the form of the ocean bed*, than any interference with the laws of fluid motion, which, however complicated in their details, are simple in their original forms. It is very certain that some of the most remarkable tides in the British coasts—as, for instance, the 18-inch spring-tide rise on one side of Fairhead, and the four-feet rise at a like distance on the other side of the same point, accompanied by terrible races and currents—similar phenomena also occurring at the Bill of Portland—are each and all mainly caused by bluff underwater cliffs, which directly reflect the tidal wave out of its course.

Plate V. is a cotidal chart of the globe, partly from Mr. Airy's treatise, and corrected from Mr. Whewell's paper above quoted; undoubtedly the coast lines give a vast amount of information touching the tide hours, and times of high water approaching various shores and islands; in one point, however, we would suggest that there is room for much greater inquiry and speculation. As the tidal wave first proceeds from the sun and moon direct, much as if the ocean were pulled up over an enormous area, and then suddenly or as rapidly dropped again, it is clear that the wave must traverse, almost unchecked, in the depths of ocean adjacent to the equator; from this region it is natural to suppose, on the same principles of which we have positive proof in our channels and estuaries, that the waves diverge in a circular form, with velocities varying as influenced by depth and friction. Unfortunately deep sea tides are beyond reach of experiment; but we imagine that it would meet the requirements of theory if the cotidal lines in the southern hemisphere were adjusted as encircling or radiating from the equator, as those in the northern side are shown to do; this would affect not the hours along shore of South America, New Holland, and the Polynesian Islands, but the supposed direction in which the tide-wave works up the coasts; and if we take this view of the theory, it may account for many anomalies in the tides of the complicated region round Singapore. Mr. Whewell's remark that the cotidal lines always run almost parallel to the shore, indicate how immediately the tide is retarded in velocity when coming out of deep water, and how large must be the radius of each progressive wave; his own remarks indicate the above hypothesis.

With regard to the semi-diurnal tide, we find it practically perceptible in the Thames, and it is also visible in the tides of the Humber. In a tidal canal branching from the Thames, which is under our management, it is found that at neap tides the inequality is highly useful by enabling advantage to be taken of the highest tide for keeping up the water to a better working level, there being occasionally nearly two feet difference; we have also experienced a similar advantage by the lower ebbing out in erecting tidal works at Plymouth.

TIDES OF RIVERS AND ESTUARIES.

With a view to a more general knowledge and comparison of the tidal phenomena of English rivers, we have formed a collection* of the principal characteristics of their tidal flow and ebb; of the velocity of the tidal wave, and other accompanying circumstances, such as the depth, width, and sectional area; and also the actual relative level of the water or tidal wave, at various points in the course of the respective rivers. We have collected the whole of the matter at the end of this article, amounting to twenty-two consecutive pages, viz.—

Tidal phenomena of the

Thames...2	pages.	Tyne......4	pages.
Waveney 3	"	Clyde......3	"
Nene......1	"	Mersey ...3	"
Humber..1	"	Dee........1	"
Tay........1	"	Severn ...3	"

And we have closed them by a schedule of the size of Docks in the United Kingdom, depth of cills, and other information, useful to shew the capability of the different ports, and accommodation in relation to their natural flow of tide, additional information on which is also given in the tables of the Tides of British Ports.

The following preliminary remarks upon each example will give all that we have been able to collect; they should be read in conjunction with the tables of the tidal phenomena relating thereto.

THE RIVER THAMES.

The river Thames has now a free tide-way up to Teddington Lock, near Richmond, but previously to the removal of old London Bridge it was, for all practical purposes, held up as by a weir at that point. Much discussion arose on the probable effect of its removal, and Messrs. Rennie conducted surveys for the city, at various periods, by Mr. Giles and others, to ascertain the probable effects; to save the reader labour of going through all the observations so ably put together by Mr. Rennie in his papers on Hydraulics, in the Reports of the British Association, we have laid together the following remarks and tables from this and other sources, endeavouring to trace down the various improvements and alterations in this great river; a careful perusal of the following statements will show to the student or others seeking for examples, the enormous advantage produced by removing obstacles to the full tidal flow.

Mr. Rennie quotes from the *Philosophical Transactions* for 1720, observations, taken in Lambeth Reach, of the Thames, by Mr. Saumarez, 8th and 19th June, 1719; we place them here in juxta-position with the present state of the river, showing the enormous changes that have been produced.

* The collection has of course been gathered from various sources, as acknowledged in each case. Unless very great liberality had been shewn to me by Mr. Rendel and other friends, I could not have attempted the labour. One endeavour has been to adopt none but what could be relied on as strictly engineering surveys, and of undoubted accuracy.

	1720. H.	1720. M.	1849. H.	1849. M.
Time of Flood Spring Tide	3	50	5	15
Ditto Ebb do.	8	40	7	5
Time of Flood Neap Tide	4	50	6	0
Ditto Ebb do.	7	35	6	20

	1720.	
Miles run by Flood Spring Tide ..	5.25	Present facts not known.
Ditto Ebb do. ..	10.50	
Ditto Flood Neap do. ..	4.75	
Ditto Ebb do. do. ..	7.75	

In the river Thames the tidal wave is now affected much less from friction and obstacles than might be expected. From reference to Mr. Lloyd's observations on the rise of the tides at Sheerness, with the mean of Mr. Lubbock's at the London Docks, it appears that in 1828—

			Feet.	Feet.
The spring tide high water at the London Docks, above the same at Sheerness, was			2.036	
				0.207
The mean high water	ditto	ditto	2.243	
				0.105
The neap tide	ditto	ditto	2.358	
				0.690
The spring tide low water	ditto	ditto	1.662	
				0.368
The mean level of the tides	ditto	ditto	2.036	
Or, taking more correctly the half difference between spring high and low water at Sheerness, the mean spring level is...			1.725	

It seems, from the above summary, that as the water decreases in height, so the height of the water's surface at London Docks above the same at Sheerness also decreases, with the exception of spring tides at the London Docks and at neap tides. The above are means, not of the highest tides, but of the tides at a particular time of the moon's southing; Trinity high-water mark at London Bridge was found by Mr. Lloyd to be 1.904 above mean spring tide high-water mark at Sheerness.

With respect to the influence of the winds on these tides; during strong north-westerly gales, the tide marks high water earlier than otherwise, and does not give so much water, whilst the ebb tide runs out later and marks lower; but upon the gales abating and the weather moderating, the tides put in, and rise much higher, whilst they also run along after high water is marked, and with more velocity of current; nor do they run out so long or so low: a south-westerly gale has a contrary effect generally, and an easterly one gives some water; but the tides in all these cases always improve the moment the weather moderates.

Comparing observations taken at spring tides, for three days in March, 1833, before Old London Bridge foundations were removed, we find that high water at London Bridge was 1 hour 37 minutes after Sheerness; whereas now, in 1851, it is only 1 hour 20 minutes at spring tides, later than at Sheerness.

	Ft.	Ins.
In March, 1833, the rise of tide at Sheerness was	18	7
Ditto ditto at Fresh Wharf............	20	5
Ditto ditto at New London Bridge	18	3

Comparing the rise of these tides with those of June, 1849, at page lxxxii, it will be seen that London Bridge (although the old fall of 2ft. 2ins. is long since obliterated) is still the culminating point of the tidal wave of the Thames, owing to the narrowness of the river at this point, and quantity of ships at anchor in the pool; thus—

	Ft.	Ins.		Time. H. M.
Spring tide, June 20th, 1849, at Deptford	20	8	...	1 15
Ditto ditto at London Bridge	20	11½	...	1 30
Ditto ditto at Battersea	19	8	...	2 0
Ditto computed for Sheerness	18	7	...	11 55

But the most striking instance of the change in the tidal head of the Thames is shewn by the following comparison of the

TIME AND HEIGHTS OF HIGH AND LOW WATER, in 1823 & 1845.

Datum 20 feet below Trinity High Water, in this and all other Tables of the River Thames.

SPRING TIDE.

Stations.	April 29th, 1823.				April 25th, 1845.			
	High Water.		Low Water.		High Water.		Low Water.	
	Time.	Height	Time.	Height	Time.	Height	Time.	Height
	a.m. H. M.	Ft. Ins.	a.m. H. M.	Ft. Ins.	p.m. H. M.	Ft. Ins.	p.m. H. M.	Ft. Ins.
London Docks	4 15	19 0	11 18	17 6	4 13	20 3	11 45	19 3
Battersea Bridge......	5 1	18 9	p.m. 0 45	8 6	4 50	20 1	0 40	5 7
Putney Bridge.........	5 13	19 0	1 5	9 8	5 0	20 0	1 15	6 4
Kew Bridge	5 40	19 7	2 20	13 5	5 15	20 2	2 20	10 8
Teddington Lock ...	6 28	21 9	4 59	20 11	6 0	20 11½	a.m. 10 0	17 8½

NEAP TIDE.

Stations.	May 5th, 1823.				May 1st, 1845.			
	High Water.		Low Water.		High Water.		Low Water.	
	Time.	Height	Time.	Height	Time.	Height	Time.	Height
	p.m. H. M.	Ft. Ins.	a.m. H. M.	Ft. Ins.	a.m. H. M.	Ft Ins.	a.m. H. M.	Ft. Ins.
London Docks	9 7	15 3	3 21	1 9	9 45	17 0	4 35	1 0
Battersea Bridge......	10 8	14 11	5 38	6 2	10 25	16 10	p.m. 6 10	5 4
Putney Bridge.........	10 31	15 2	6 35	8 3	10 55	16 11	a.m. 7 10	6 11
Kew Bridge	10 49	15 10	8 15	11 8	0 0	19 0	9 15	11 0
Teddington Lock......	11 50	19 4	10 40	19 0	p.m. 0 20	18 4½	1 0* p.m. 2 30	17 10½ 17 10½

* This is evidently not the time of the commencement of the flood, but the time of low water; the down stream continuing for some hours afterwards.

COMPARATIVE SECTIONS BETWEEN WESTMINSTER AND LONDON BRIDGES.

Taken in 1823 and 1831 by Messrs. Rennie, and in 1845 by Mr. Page.

Locality.	Area below Low Water.			Area below Trinity High Water.		
	1823.	1831.	1845.	1823.	1831.	1845.
	Sup. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.	Sq. Ft.
230 yards north of Westminster Bridge	3,939	3,487	5,642	19,348	20,046	20,953
Near Whitehall Stairs	4,757	6,570	6,845	21,168	23,660	24,744
Near Hungerford Stairs	3,891	3,920	6,458	19,974	21,822	24,768
Waterloo Bridge	3,752	3,947	4,276	20,570	20,905	22,705
Bouverie Street	4,332	3,900	6,153	18,291	18,210	22,005
Between Blackfriars & Southwark Bridges	3,976	3,381	4,320	16,958	17,203	15,460
					1832.	1834.
London Bridge	..	..	..	7,360	17,650	17,600

TABLE OF VELOCITIES OF FLOOD AND EBB TIDE.

Giving the effect of removing old London Bridge.

	First of Flood.		Last of Flood.		First of Ebb.		Last of Ebb.	
	1831.	1833.	1831.	1833.	1831.	1833.	1831.	1833.
Between	Ft. per Min.	Ft. per Min.	Ft. per Min.	Ft. per Min.	Ft. per Min.	Ft. per Min.	Ft. per Min.	Ft. per Min.
Westminster & Waterloo Bridges	139.8	150.4	155.9	170.0	163.8	170.4	169.4	191.3
Waterloo & Blackfriars Bridges	149.4	172.9	184.8	209.7	186.0	218.6	196.3	238.9
Blackfriars & Southwark Bridges	158.1	174.2	259.6	268.1	262.3	277.7	252.0	295.6
Southwark & London Bridges	170.6	156.6	293.4	254.4	363.0	317.6	337.5	287.1

AVERAGE LEVELS OF HIGH AND LOW WATER, IN 1832, 1833, AND 1834.

Years.	No. of Tides in each Year.	Putney Bridge.		Kew Bridge.		Richmond Br.		Teddington Lk.	
		MEAN LEVEL OF		MEAN LEVEL OF		MEAN LEVEL OF		MEAN LEVEL OF	
		High Water.	Low Water.	High Water.	Low Water.	High Water.	Low Water.	High Water.	Low Water.
		Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.
1832	88	18 1	8 4	18 8	11 11	19 3	15 9	19 7	19 4
1833	84	18 6	8 8	19 2	12 6	19 9	16 4	19 2	20 0
1834	89	18 2	7 8	18 6	10 11	18 10	14 7	19 8	18 3

VELOCITIES OF FLOOD AND EBB TIDE, 19th JUNE, 1834.

(Wind W.S.W. Fresh breeze and clear). From experiments by Messrs. Rennie.

Stations.	Distance from London Bridge.	Flood Tide. (*Read downwards.*)			Ebb Tide. (*Read upwards.*)		
		Time.	Height at London Bridge.	Velocity per minute.	Time.	Height at London Bridge.	Velocity per minute.
	Miles.	h. m.	Ft. Ins.	Feet.	h. m.	Ft. Ins.	Feet.
London Bridge	0.00	8 6	2 9	0.00	7 34	0 10	296.56
Southwark Bridge ...	0.28	8 30	5 1	61.60	7 29	1 0	275.44
Blackfriars Bridge...	0.75	8 53	7 0	190.08	7 20	1 2	249.04
Waterloo Bridge ...	1.34	9 14	8 7	147.84	7 7	1 6	198.88
Hungerford Market	1.50	9 23	9 2	94.16	..	..	..
Westminster Bridge	2.00	9 36	10 9	202.40	6 50	1 11	224.40
Horseferry..............	2.42	9 50	11 2	160.16	6 40	2 2	198.00
Vauxhall Bridge......	2.95	10 3	12 1	205.04	6 26	2 7	214.72
Chelsea Coll. Stairs	4.21	10 34	14 2	218.24	5 55	3 6	181.28
Chelsea Bridge	5.04	10 55	15 10	207.68	5 31	4 4	176.00
½-mile above ditto ...	5.54	11 9	16 10	188.32	5 16	4 10	195.36
1 mile ditto	6.04	11 20	17 6	240.24	5 2	5 4	176.00
1½ do. (Wandsworth)	6.54	11 31	18 0	240.24	4 47	5 11	195.36
Putney Bridge.........	7.48	11 50	18 9	290.40	4 21	7 0	67.36
2½ miles..................	7.54	11 53	18 10	90.64	4 16	7 3	142.56
3 miles	8.04	12 6	19 3	211.20	3 58	8 0	146.96
3½ miles..................	8.54	12 20	19 4	188.32	3 40	8 10	176.00
4 miles	9.04	12 30	19 4	264.00	3 25	9 5	146.08
Hammersmith Brdg.	9.20	12 35	19 2	176.00	3 19	9 7	185.68
5½ miles..................	10.54	*1 15	17 1	176.00	2 35	11 11	110.00
6 miles	11.04	1 35	15 7	132.00	2 11	13 3	119.68
6½ miles..................	11.29	1 45	14 11	132.00	2 0	13 11	10.56
High Water at London Bridge	..	p.m. 12 30	19 4	..	p.m. 12 30	19 4	..
Low Water	..	a.m. 7 35	0 3	..	7 45	0 9	..

In 1823 Mr. Giles made the average velocity of flood tide between London Bridge and Putney Bridge .... 220 feet per minute.
Do. Southwark and Westminster 176 „ „

The velocity of ebb tide he found to be

Between Westminster and Waterloo Bridges ..... 176 „ „
„ Waterloo and Blackfriars Bridges ...... 198 „ „
„ Blackfriars and London Bridges .... 242 „ „

Finally, we give from Mr. Rennie
The sectional area at Old London Bridge, below Trinity High Water Level—

Before Removal in	1832	....	8,700 sup. feet.
After do.	1834	....	17,600 do.

		Greatest. ft.	Greatest. in.	Least. ft.	Least. in.
At Old London Bridge the fall through was,	in 1832 ..	3	6	1	10
Ditto do. do.	1834 ..	0	5	0	3
Range of Spring Tides	in 1832 ..	16	9		
Ditto do.	in 1834 ..	19	9		
Low water springs below Trinity datum ..	in 1832 ..	15	5		
Ditto do. do. ..	in 1834 ..	20	3		

The foregoing remarks are in a great measure drawn from Mr. Rennie's treatise. We have embodied them with other observations at our disposal, in order to give a picture of what has occurred by the changes of this important river, thus offering condensed data for future comparisons. The rapid changes even now daily occurring by ballasting, and by the increased area and flattening of the bed, *originally* caused by the removal of Old London Bridge, renders the Thames a highly instructive example; its present state is brought up to 1849, at pages lxxxii–iii.

THE RIVER WAVENEY

Has some of its phenomena given in the tables at pages lxxxiv-v-vi; united with the Yare, it is emptied by a long narrow channel at Yarmouth Pier, about 1½ miles below the town; here it has a great obstruction in the old bridge, which will be shortly removed, and doubtless have a very happy effect upon the navigation. Our tabulated observations pass above Yarmouth, where the river spreads into a large lake called Burgh Flats; they are continued by St. Olave's Bridge, where the Yare has divided off from the Waveney proper, and pass on to Beccles; we give also the simultaneous height at the Mutford Lock (Waveney side), and at Lowestoft Pier. This river is well known to be extremely sluggish in its tidal flow, and the form of its mouth and the wide expanse of Burgh Flats, with a great want of a deep channel, give all the conditions for bad propagation of the wave, consequently small oscillation of tide, and deficient drainage. Mutford Lock is remarkable as a point where local jealousy of interference with back water, belonging to the Yarmouth River, has caused the construction of a lock and gates so arranged as to prevent any tidal flow passing to or from the Lowestoft entrance of the tidal wave; if the passage were free, these two points, viz., the north side of Mutford Lock, and Lowestoft Pier, being only four miles distant, would have but little difference in their tidal flow, while a greatly increased flow would be carried on towards St. Olave's Bridge, with advantage to all interests, and prejudice to none, if proper arrangements were made simultaneously with relation to the Yarmouth river.

THE RIVER NENE.

In the year 1813 the Commissioners of the North Level (drained by the river Nene) applied to Mr. Rennie for advice, which he gave in the following year; from his observations it then appeared that the fall at low water from Sutton Wash to Crab Hole (below the sands of the Wash) was 12 feet in about 4 miles; from the surface of the water at Gunthorpe Sluice to Crab Hole, a distance of 5½ miles, the fall was 13 feet; from Guyhern to Crab Hole, a distance of 17 miles, the fall was 14 feet 6 inches; and from Peterborough Bridge to the same point, a distance of 30½ miles, the fall was only 18 feet 6 inches.

It appeared, therefore, evident that the great bar to the discharge of the waters of the Nene, and of course to the general drainage of the fens, was the high and shifting sands between Gunthorpe Sluice and Crab Hole, independently of the narrow and confined state of the river above; Mr. Rennie, therefore, recommended the river to be carried by a new cut, of a suitable capacity, across the marshes to Crab Hole, 5½ miles in length.

The Cut was carried into execution under the direction of Messrs. Telford and Rennie, and completed in 1834; the original dimensions are shewn at page xiv, but the section has deepened and generally improved since completion; its effects exceeded the most sanguine expectations, having reduced the fall between Crab Hole and Gunthorpe to about three inches per mile, where it was formerly more than two feet per mile; low water below Sutton Bridge being now five feet below that at King's Lynn, on the Ouse. The scouring effect was so great, that the Sutton Wash Bridge, erected during the progress of the outfall, was in great danger of being undermined, requiring stone to be thrown in, much to the detriment of greater improvement of the river. This has been amended last year by the construction of a new bridge, and the old one is now being removed (1851). There is no doubt that the cill of the North Level Sluice, laid during the making of the Nene outfall, will shortly be capable of being lowered more than two feet. For the present surface fall see the Table, and also page xiv. We have these facts from Mr. Utting, Surveyor to the Commissioners, who states that the Nene outfall lowered the water at the north level sluice ten feet; in the town of Wisbeach, spring tides rose four feet only, and now rise thirteen feet; and neap tides, which in 1769 did not reach the town, now rise nine feet.

Notwithstanding the enormous advantage of this outfall to the river below Wisbeach, yet the narrowness of that town and its bridge have the effect of keeping up the waters of the upper Nene, so that there is ordinarily two feet of fall through Wisbeach at low water.

The tidal flow and sectional areas of the Nene are given at page lxxxvii, from our own observations, taken for Mr. Rendel. Attempts are now being made to obtain powers for improving the river through and above Wisbeach; but an enormous area of land which should have drained by the Nene, with an advantage of five feet fall, is now carried by the Middle Level Drainage into the Ouse; there is, however, ample inducement for an improvement of the Nene, both in respect of drainage and of navigation; for the banks and narrows above Wisbeach, and especially Guyhern, render the river little better than a shallow pond; although, properly improved, it would have a very free and considerable tidal ebb and flow, even at neaps.

THE RIVER OUSE,

Another of the rivers emptying into the Wash, has a marked bore which, like that of the Severn, is created by the shoals at the mouth below Lynn, causing a greater fall at the outlet than further up the river. We believe this will be found to be universally the case where the bore prevails. The ocean tidal wave comes up from deep water, and meeting with the sudden rise and resistance of the bed, the wave assumes a head which, too great for its depth, topples over in the characteristic form of the bore.

The Eau Brink Cut, originally projected by Mr. Nathaniel Kinderley, in the year 1720, was completed by Mr. Rennie in 1825, according to the award of Messrs. Huddart and Mylne; its object was to conduct the waters of the river Ouse by a direct cut across the marshes from Eau Brink to Lynn, of about two miles and a half in length, instead of allowing them to flow by the old circuitous channel of upward of five miles in length.

The area of Eau Brink Cut, just below Freebridge, at low water spring tides, or 2′ 3″ on Freebridge gauge, is 2,620 square feet, the depth then being 11′ 9″ and width at water line 312 feet.

The area at high water springs, rising to 16′ 9″ on the same gauge, is 7,879 square feet, the depth then being 26′ 3″ and width at water line 412 feet.

The surface fall at Eau Brink Cut is given at page xiv.

In December, 1821, the tide rose on the average eleven feet ten inches on the cill of Old Denver Sluice; while at low water the average depth on the cill was 9·6 inches.

Since the completion of the Eau Brink Cut, the results have been—

That the low-water mark has fallen six feet lower than it formerly stood at Denver Sluice, and from eight to nine feet at Eau Brink.

That the spring tides now rise at Denver Sluice thirteen feet, and neap tides eight feet.

That the river has deepened between Denver Sluice and Eau Brink ten feet upon the average, and its general sectional area has increased from one-fourth to one-third.

That the low-water mark in Lynn harbour has fallen four feet, and the navigable channel in Lynn harbour has deepened seven feet; and that where there were formerly twelve feet in depth of water in the intercepted bed of the old Ouse between Eau Brink and Lynn, there is now a tract of 900 acres of land under cultivation, all of which has been effected by the process of warping.

The tide in the Eau Brink flows three hours, and rises in that time fifteen feet, at spring tides, thus leaving nine hours of ebb; the young flood then assumes all the characteristics of a bore, rising at the first two minutes from one to three feet, and subsiding again, for a short time, to half the first height when the wave has passed on.*

Notwithstanding the enormous improvement by the Eau Brink Cut, low water spring tides at King's Lynn are still about five feet higher than in the roads at the entrance of the river, owing to the circuitous course of the channel, and the prevalence of bars and banks of sand and mud; to remedy this and to aid the formation of the great Estuary of the Wash enclosure, Sir John Rennie is now cutting an outfall from opposite King's Lynn to the Roads, a length of four miles, which will have the effect of bringing dead low water practically up to Lynn, or, in other words, lower the water at the end of Eau Brink Cut nearly five feet.

This new cut is 250 feet wide at bottom, and 500 feet wide at top, and 32 feet deep; it is 14′ 3″ deep at low water spring tides, or 2′ 3″ on Freebridge gauge, with an area of 3,960 square feet, and width at water line of 355 feet.

The depth of the cut at high water spring tides, or 16′ 9″ on Freebridge gauge, will be 28′ 9″ with an area of 9,990 square feet, and width at water line of 474 feet.

The cut passes inland for two miles, and the remaining two miles crosses the channel and sand banks of the estuary into Lynn deeps; the first portion containing about four millions of cubic yards, has been nearly finished in the short space of fourteen months, by the vigorous appliances of Messrs. Peto and Betts, forming a work at the present moment highly interesting to an engineer.

THE RIVER HUMBER.

We have not access to any engineering survey of the tides of the Humber, and can therefore only give, at page lxxxviii, the curves of spring and neap tide at Grimsby; diurnal inequality appears to be strongly

* This is chiefly from Mr. S. Rennie's Report on Hydraulics.

marked here. Humber tides are strong, and, like the Ouse, Severn, and Mersey, carry much silt, depositing it capriciously wherever an opportunity offers, and readily cutting out deep channels in the bed when tidal stream is diverted on any spot, from general or accidental causes. The great tidal power of this river and its deep channels offer great facility for the effective drainage of the vast area of marsh lands bordering upon its ramifications, as is also the silt in their warping and fertilization.

THE RIVER TAY

Is a river subject to great floods, from the mountainous character of its sources, and other causes, much aggravated, occasionally, by the effect of the deep Falls on Lock Tay. It is interesting as having had great improvements effected on its upper tidal portion, from Newburgh to Perth, under direction of Messrs. Stevenson, of Edinburgh, who dredged out in this division 815,000 tons, between 1835 and 1841, at an expense of about £53,000.

In a report, made in 1845, by these gentlemen, to the conservators of the river, they describe the Tay as draining 2,283 square miles, and having a *mean* discharge at Perth of 218,158 cubic feet per minute*; about seven miles below that city, the Earn adds its volume, giving, by the same authority, a *mean* discharge of 54,959 cubic feet per minute.

The head of navigation at Perth is 23 miles from Dundee, and 32 from the German Ocean, but the tide extends to 2½ miles above Perth.

The extreme tides from neaps to springs:—

At Dundee,	range from	7 to 18 feet.
At Newburgh,	„ „	6·5 to 15 „
At Perth,	„ „	6 to 13 „

The depth of water in the Frith ranges from 36 to 54 feet at high water, the bar having about 34 feet at spring tides. From Flisk point to Newburgh the river gradually shoals from 30 feet to 18 feet; and from Newburgh to Perth, from 18 to 15 feet at high water spring tides; the navigable breadth being scarcely ever less than 100 yards.

Previous to the commencement of Messrs. Stevenson's improvements, the river was impeded by fords and salmon weirs, or fishings, so that vessels drawing from 10 to 11 feet frequently missed even spring tides. The river was also obstructed by large boulders. The works executed were, in the words of the Report:—

"*First.*—The fords, and many intermediate shallows, were deepened by steam dredging; and the system of harrowing, which was so successfully practised on the Mersey, was employed on some of the softer banks on the lower part of the river.

"*Second.*—The large detached boulders and fishing-cairns, which obstructed the passage of vessels, were removed by means of lighters, mounted with cranes, and by pontoons.

"*Third.*—Three subsidiary channels at Sleepless, Darry, and Balhepburn islands, were shut up by means of embankments formed of the produce of the dredging, so as to confine the whole of the water to the navigable channel.

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* According to this, the amount run off the surface would represent about 21·5 inches in the year. The ordinary summer run (July) of the Tay at Perth, amounts to 60,000 cubic feet per minute, or 26 cubic feet per minute per square mile, but in a dry autumn there is not above one-third of this quantity. High floods in the Tay have discharged, for more than twenty-four hours consecutively, as much as 660,000 cubic feet per minute, or 286 cubic feet per square mile, or nearly three-sixteenths of an inch in depth over the surface run off.

"*Fourth.*—In some places the banks on each side of the river beyond low water mark, where much contracted, were excavated and removed, in order to equalize the currents, by allowing sufficient space for the free passage of the water.

"*Fifth.*—A great part of the dredged material was deposited along the banks of the river in a careful manner, so as to form new Fishing Beaches, to compensate for the removal of others."

The commercial effect of these improvements shew that in 1833, 12 vessels, of 100 to 144 tons and upwards, frequented the port; while in 1844 there were 37 vessels, from 100 to 400 tons, and the customs rose from £2,969 to £16,837.

At page lxxxix we have given, from Messrs. Stevenson's report, the chief phenomena of the velocity of the tidal wave and fall of the river surface, which the reader will observe have a close relation to each other. For instance, between Newburgh and Perth the low water surface fall

In 1833 was ·467 feet per mile.	Velocity of wave 301 feet per minute.	
In 1844 „ ·233 „	Velocity of wave 452 „	

So that the tide begins to flow now fifty minutes sooner at Perth, than before the improvements.

The results of observations in 1833 and 1844, at Newburgh, shew that the duration of flood and ebb tides at that place are unchanged. The times are as follows:—

		H.	M.
Spring tides	flow	4	20
„	ebb	7	20
Neap tides	flow	4	30
„	ebb	6	45

At Perth, in 1833,—

Spring tides	flowed	2	20
„	ebbed	7	0
Neap tides	flowed	3	15
„	ebbed	7	0

At Perth, in 1844,—

Spring tides	flowed	3	10
„	ebbed	7	0
Neap tides	flowed	3	10
„	ebbed	7	0
Increase of duration flood at Perth		0	50
In 1833 the river ran at its natural level at spring tide		1	45
In 1844 it runs at its natural level at spring tide		1	0
Giving a decrease in the time of standing at low water, or in the absence of tidal influence at Perth, at spring tides, of		0	45

We have abstracted these facts at some length, because the Tay is a most striking instance of the advantages of expediting the tidal wave and flow, by the formation of a uniform passage, without any violent changes in the form of the channel itself, and at a comparatively moderate expense.

THE RIVER TYNE,

From want of improvement, has seen other ports rapidly outstrip its ancient pre-eminence; the river suffers grievously from a bar, and also from being subject to great floods at the point where the tide meets, which in the course of ages have brought down heavy gravel deposits. These floods, from want of proper train and regularity of conservation, do great harm when they might be productive of good. The bar of the Tyne has a very serious effect on its general feature, being literally a weir preventing the proper flow and ebb of the tidal waters, which is again further checked by the large expanse of Jarrows lake within the river mouth (like the Burgh flats on the Waveney), which aids greatly in checking the concentration of tidal flow up stream. Plate VII. gives the form of the wave when high water at Newcastle.

THE RIVER CLYDE

Has had large sums of money spent in deepening its bed and regulating its banks. These works have been similar to those described on the Tay, and have been equally effective. High water at springs now rises nearly two feet higher than before the improvements, and the draft of water is increased from six feet to fourteen or fifteen feet, while the time of high water at Glasgow is accelerated twenty minutes, and the time of young flood far more, and on the ebbing out has been equally delayed. At pages xciv-v-vi, are the chief phenomena of the river, placed in a similar manner with those of the Tay.

THE RIVER MERSEY

Is too well known to require much reference. We have given, in Plate VI., the form of tidal wave, from observations taken with extreme accuracy, in the parliamentary contest for the Birkenhead Docks. The river is loaded with sands at its mouth; but the vast body of water passing in and out offers a powerful check on the counter effect of winds and waves on the vast shifting sands. In the diagram, the growing up of the tidal wave, at the narrow part opposite Liverpool, the faltering again at the wide expanse between Eastham and Ellesmere Port, and the heading up again when narrowing at Runcorn, is shewn very strikingly. The great rise and volume of tide, and straight even sides not too far within the mouth, are the great safeguards of the port of Liverpool; the ample dock space, and cheapness of construction from the rock foundation, and tidal ebbing off, give the great pre-eminence of Liverpool as a port. The phenomena of springs and neaps from the mouth, to Warrington the head of the tidal flow, are given at pages xcvii-viii-ix.

THE RIVER DEE,

In form, is strikingly the reverse of Liverpool; an injudicious mode of enclosure, unaccompanied by proper dredgings, has rendered useless what might have been a great improvement of its upper course; while the want of a proper application of capital lower down has permitted evils to gather strength.

Even with the serious sand banks at the mouths, and the want of a great natural channel inside, to give direction and effect to the currents, we still are of opinion that a sum of money, boldly spent, would effect a vast revolution in the commerce of the Dee, and with great benefit; for Chester is well placed for commercial intercourse with the mining districts and potteries.

THE RIVER SEVERN.

The river Severn was surveyed in 1849 by Captain Beechey, F.R.S., by order of the Lords of the Admiralty. A short statement accompanies his elaborate maps, and from these documents we have compiled the information given at pages ci., cii., ciii., Captain Beechey's labours are here condensed into a form that will be best understood by a careful examination of the tables. The phenomena of the bore are shown to fluctuate in the inverse ratio of the velocity of the tidal wave, and in connexion with this, it will be observed that the fall of the Severn *increases* as it approaches the sea; with this fact the cause of the bore is closely connected; as we have before hinted in the case of the Ouse at King's Lynn, in the best form of rivers, the surface fall generally decreases in approaching to the tide way.

Low water at spring tides below Lidney is (as ordinarily) lower than at neaps; but above Lidney the reverse takes place;* this Captain Beechey thinks is occasioned by the waves throwing more water into the river than can escape at spring tides. The form of high and low water springs and neaps is shown at page ci. It will be seen that the maximum height of springs is between Framilode and Rosemary, dropping downwards to Haw Bridge, after which it ascends, until lost in the ordinary slope of the river. The diagram, Plate VII. shews the most characteristic surface lines.

The table at page ciii shows the progress of the crest of the tide-wave, the rate of the bore and the rate of the stream answering to the various ranges of the tide at Sharpness, including times when the river was under the influence of strong freshes. Between Sharpness and Hock Crib, the wave passes at an unusually rapid rate. And Captain Beechey thinks it is possible that the perpendicular surface of the cliff at Hock Crib, and its situation at right angles to the progress of the wave, may occasion a premature high-water at that particular spot. In the following table, therefore, Hock Crib is omitted, and the interval between Sharpness and Newnham is taken.

TABLE OF VELOCITY OF THE TIDAL WAVE AND BORE OF THE SEVERN AT SPRING TIDES.

Between—	TIDAL WAVE. Feet per Min.	BORE. Feet per Min.
Beachley and Sharpness	1,600	374
Sharpness and Newnham	1,944	587
Newnham and Framilode	1,900	475
Framilode and Rosemary Point	992	820
Rosemary and Stonebench	870	526
Stonebench and Haw Bridge	1,053	138
Haw Bridge and Hythe Bridge	729	123
Hythe Bridge and Upton Bridge	1,053	820

* This is not unfrequently the case in rivers having many shoals and considerable fall in their bed.

"After passing Framilode, the rate of the tide-wave suffers a material diminution between that place and Rosemary Point. The river, after much encumbrance from sand-banks, assumes its average contracted dimensions, from which it afterwards scarcely deviates to any amount. There are besides some very sharp turns in the river at and above Rosemary, all of which assist in retarding the progress of the wave, so that its rate is reduced to about 10 miles an hour, or half the rate at which it travels at Sharpness; and at this reduced rate nearly it continues its progress up the river as far as the observations can be made with accuracy.

"*The Bore*, or the foot of the wave, travels at a very irregular rate; its advance at all times depends upon the magnitude of the tide; but, in addition to the irregularity arising from this cause, its speed is affected by particular winds, by the shallowness of the river, and especially by low dry sand-banks. The inclination of the surface of the water it has to surmount also appears to produce a sensible effect upon its rate of travelling. Thus, between Beachley and Sharpness, where the ascent of the low-water surface is 1·75 feet per mile, the bore advances at the rate of 870 feet per minute; and between this place and Rosemary Point, where the ascent is 1·12 feet per mile, the rate of the bore is still only 550 feet per minute; but from Rosemary upwards, where the ascent is only 0·12 foot per mile, the rate increases to upwards of 1,300 feet per minute, and this easy ascent continuing, the wave continues to roll up the river at a speed nearly double that of its original rate. It must, however, be borne in mind that in all that part of the river where the rate is so small, the river is encumbered with sand-banks, which are the causes also of the rapid descent of the river-surface, the space being occupied by numerous small rapids.

"On a comparison of the rates of the tidal wave and the bore, it appears that, in the early stage of the tide, the crest of the tide-wave is rapidly overtaking the bore and, consequently, momentarily increasing the height of it; and there can be no doubt that this retardation of the foot of the wave, occasioned by friction of shallows and sand-banks, is the primary cause of the bore. Above Rosemary, the bore, unobstructed by sand-banks, rolls on at a rate which more than equals that of the crest of the wave; and the phenomenon is shortly found to diminish, to lose its wave character as it proceeds, and to become scarcely perceptible above the Partings (Gloucester).

"When the reaches of the river are straight, the bore travels evenly up the river; but at the turnings it is thrown off towards the further side, where it rises higher than in the straight reaches; thence it recoils and impinges upon the opposite shore, and so, like a disturbed pendulum, it oscillates from side to side, and only regains its steady course when the reaches lengthen.

"The highest tide of the year rolled up the Severn on the 1st of December. There was about 2 feet of water above the ordinary summer level in the river, and the morning was calm and favourable to the phenomenon. The stream at low water ran down at the rate of 250 feet per minute, until the bore came rolling up the river with a breast from 5 to 6 feet high at the sides, and 3 feet 6 inches in the centre. The wave was glassy smooth, and as it advanced towards a spectator stationed at Stonebench, a singular effect was produced by the distorted surface of the wave reflecting the rising sun, and brilliantly illuminating the stems and branches of the wood skirting the river as the bore passed along; an effect which greatly enhanced the interest of the phenomenon. The stream turned at the instant after the bore passed, and ran at the rate of 380 feet per minute, which was about half the average rate of the bore, which varied from 12 to 7 miles per hour.

"In the table the effect of the fresh, or a certain depth of water in the river, upon the advance of the bore is remarkable. At dry periods the great obstruction to the progress of the bore lies between Sharpness and Bullopill; and, at such times, the many dry sand-banks prevent the bore attaining a rate greater than about 4 miles an hour, as shewn in the table; but when the river is under the influence of freshes, and the water raised, covering some of the banks, it appears to roll on at a rate of 10 miles an hour in opposition to the stream, which about Hock Crib is there running down at the rate of upwards of 4 miles an hour.

The state of the surface fall of the river Severn in flood, which we have tabulated in conjunction with the sectional area, &c., at page cii., will be found of great value, being a rare example; at pages xxvi., xxvii., we have given a short statement of the discharge of this river in the flood of December 4th, 1849, and its relation to the drainage area on that day. Plate VII. gives the form of spring tide of this river, with its summer low water and flood surface.

CONCLUDING REMARKS.

We have now finished our sketch of the different rivers of which the succeeding pages afford the date referred to; the object has been to pourtray the actual conditions of things and their effects; such as the velocities of the tidal waves, sectional area, width, depth, &c., of each case; so that any one wishiug to search for a precedent as it were, to shew what may be expected, under given circumstances, can here find, at all events, an approximation to the investigation Much more could be done if professional men would find time to follow up the subject, and we have an earnest hope that this will be done. Constant calls from our daily avocations have broken in upon and frequently destroyed the work of long previous consideration, which has had again to be taken up at a great sacrifice of time and labour. In the labour we have, at all events, found that there is a mine of unexplored phenomena open to inquiry; the great aim of our own study has been to trace out the bearings of the laws of gravity, with which the Tables commence, and which determine all hydrodynamic computation, and to shew how they are affected by friction, and other resistances; all are mere modifications of this first cause, and the practical result of their various forms and conditions is what the Engineer requires for a skilful adaptation of his works.

The succeeding pages contain the tides of the several rivers we have described. At the end will be found a few diagrams, shewing the form of tidal flow, and the section of the river bed of the Mersey, Severn, Tyne, and Nene; preceded by the tide charts of the Irish and English Channels, referred to in the abstract of Captain Beechey's paper; there is also added a map of the world, with cotidal lines from Airy and Whewell's maps.

TIDES OF THE THAMES.

TABLE OF THE RISE AND FALL OF A SPRING AND NEAP TIDE

At the undermentioned points, taken simultaneously from the Ordnance Metropolitan Survey observations, in 1849.

Note.—Zero is 20 feet below the Ordnance datum or mean half-tide level at Liverpool, which is 12.5 below Trinity high water standard.

SPRING TIDE, June 20th, 1849.				NEAP TIDE, June 30th, 1849.			
TIME.	Deptford.	London Bridge.	Battersea.	TIME.	Deptford.	London Bridge.	Battersea.
H. M.	Feet.	Feet.	Feet.	H. M.	Feet	Feet.	Feet.
7 30a.m.	13.62LW	15.00	17.25	30a.m.	24.C7	23.70	20.90
8 0 "	13.66	14.25	16.60	8 0 "	25.78	25.40	22.55
8 30 "	15.43	14.66	16.05	8 30 "	27.32	27.00	24.10
9 0 "	18.27	17.60	15.60LW	9 0 "	28.71	28.45	25.75
9 30 "	20.85	20.80	17.75	9 30 "	29.62	29.60	27.15
10 0 "	23.56	23.05	19.80	10 0 "	30.10	30.20	28.50
10 30 "	25.77	25.40	22.15	10 30 "	29.70	30.30	28.95
11 0 "	27.68	27.40	24.35	11 0 "	28.22	29.30	28.80
11 30 "	29.18	28.80	26.30	11 30 "	26.47	27.60	27.50
12 0 "	30.52	30.30	27.85	12 0 "	24.67	25.90	26.10
0 30p.m.	31.68	31.60	29.35	0 30p.m.	23.10	24.40	24.70
1 0 "	32.73	32.80	30.80	1 0 "	21.65	23.00	3.45
1 30 "	32.85	33.45HW	31.85	1 30 "	20.33	21.60	22.25
2 0 "	31.73	32.75	32.15HW	2 0 "	19.00	20.30	21.10
2 30 "	29.64	30.95	31.20	2 30 "	17.90	19.20	20.15
3 0 "	27.43	29.00	29.20	3 0 "	16.21.	18.10	19.15
3 30 "	25.48	27.00	27.50	3 30 "	16.08	17.15	18.35
4 0 "	23.73	25.30	26.10	4 0 "	15.49	16.30	17.65
4 30 "	22.12	23.80	24.70	4 30 "	15.80	15.90	17.00
5 0 "	20.56	22.25	23.40	5 0 "	17.13	16.80	16.40
5 30 "	19.14	20.85	22.10	5 30 "	18.62	18.45	16.40
7 55a.m.	13.60LW	.. ..		10 5a.m.	30.15HW	.. ..	.. ..
8 15 "	.. ..	14.15LW		10 20 "	.. ..	30.30HW	.. ..
1 15p.m.	33.14HW	.. ..		10 40 "	.. ..	.. ..	29.05HW
				4 10p.m.	15.39LW	.. ..	.. ..
				4 40 "	.. ..	15.80LW	.. ..
				5 20 "	.. ..	.. ..	16.10LW

VELOCITIES OF THE HEAD AND FOOT OF A TIDAL WAVE,

From the above observations.

SPRING TIDE, June 20th, 1849.

STATIONS.	Distances Apart.	Tidal Range.	Interval of Passage of		Rate per Minute.	
			Foot of Wave.	Head of Wave.	Foot.	Head.
Between	Feet.	Feet.	Mins.	Mins.	Feet.	Feet.
Deptford and London Bridge	20,600	19.54D	20	15	1,030	1,373
London Bridge and Battersea......	25,700	19.30L	45	30	571	856.6
Deptford and Battersea...............	46,300	16.55B	65	45	712.3	1028.8

NEAP TIDE, June 20th. 1849.

STATIONS.	Distances Apart.	Tidal Range.	Interval of Passage of		Rate per Minute.	
			Foot of Wave.	Head of Wave.	Foot.	Head.
Between	Feet.	Feet.	Mins.	Mins.	Feet.	Feet.
Deptford and London Bridge	20,600	14.76D	30	15	686.6	1,373.2
London Bridge and Battersea......	25,700	14.50L	40	20	642,5	1,285.0
Deptford and Battersea...............	46,300	12.95B	70	35	661.4	1,323

TIDES OF THE THAMES.

VELOCITIES OF THE HEAD AND FOOT OF A TIDAL WAVE,

At a Spring and Neap Tide, from St. Katharine's Docks to Teddington Lock, from Mr. Page's observations in 1845.

SPRING TIDE, April 25th, 1845.

Names of Stations.	Distances apart.	Tidal Range	Interval of Passage of Foot of Wave	Interval of Passage of Head of Wave	Rate per Minute. Foot.	Rate per Minute. Head.
Between	Feet.	Ft. In.	Mins.	Mins.	Feet.	Feet.
St. Katharine's Docks and Battersea Br.	29,160	19.75K	70	37	429	788
Battersea Bridge and Putney Bridge	15,840	14.50B	35	10	452.6	1,584
Putney Bridge and Kew Bridge	29,700	12.67P	65	15	457	1,980
Kew Bridge and Teddington Lock	26,400	9.49K	..	45	..	587
St. Katharine's Docks and Tedding. Lock	101,100	3.25 T	..	107	..	945

NEAP TIDE, May 1st, 1845.

Names of Stations.	Distances apart.	Tidal Range	Interval of Passage of Foot of Wave	Interval of Passage of Head of Wave	Rate per Minute. Foot.	Rate per Minute. Head.
Between	Feet.	Ft. In.	Mins.	Mins.	Feet.	Feet.
St. Katharine's Docks and Battersea Br.	29,160	15.50K	85	40	343	729
Battersea Bridge and Putney Bridge	15,840	11.50B	..	30	..	528
Putney Bridge and Kew Bridge	29,700	10. 0P	..	20	..	1,485
Kew Bridge and Teddington Lock	26,400	6.16K	..	65	..	406
St. Katharine's Docks and Tedding. Lock	101,100	0.50 T	..	155	..	652.6

RESULTS OF THE TIDAL OBSERVATIONS,

TAKEN FOR THE ORDNANCE SURVEY OF THE METROPOLIS,

BETWEEN 19th JUNE and 19th JULY, 1849,

Taken in 10 Minutes' observations.

The zero of the heights is 20 feet below Ordnance datum or mean half-tide at Liverpool.	Deptfrd.	London Bridge.	Battersea.
	Feet.	Feet.	Feet.
Highest High Water observed during the month	33.14	33.45	32.15
Lowest Low Water " "	10.81	11.75	14.45
Mean High Water for the month	30.98	31.23	29.95
" Low Water "	13.06	13.65	15.04
Mean Half-tide "	22.02	22.44	22.50
Mean Half-tide at London, above approximate Half-tide at Liverpool	2.02	2.44	2.50

HEIGHT OF TRINITY HIGH WATER MARKS ABOVE ZERO.

Mark at Lomer's Quay, Billingsgate	32.36	Feet.
" Hermitage Entrance, London Docks	32.50	"
" Shadwell Entrance, London Docks..............................	32.59	"
" Limehouse Entrance, West India Dock Basin....................	32.75	"
" " South Dock	32.71	"
" Blackwall Entrance, South Dock..................................	32.73	"
" " West India Dock	32.77	"

TIDES OF THE WAVENEY.

TABLE OF THE RISE AND FALL OF THE TIDE

At various points, taken simultaneously from the mouth of the river at Yarmouth to Beccles, and at Lowestoft.

Datum line 5 feet below Old Zero at Mutford Bridge.

NEAP TIDE, March 21st, 1850.

Time.			Yarmouth Pier.		Yarmouth Bridge.		Burgh Flats.		St. Olave's.		Burgh St. Peter's.		Beccles		Mutford Lock, N. Side.		Lowestoft Pier.	
H.	M.		Ft.	Ins.	Ft	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
6	0	a.m.	3	3¼	4	0¼	4	6⅝	5	1¼	5	3⅝	5	5	5	5⅛	3	6
6	30	„	2	8¼	3	9¼	4	4⅝	5	0¼	5	4¼	5	5⅛	5	5¼	3	0
7	0	„	2	5¼	3	5¼	4	2⅝	4	11¼	5	3⅝	5	5¼	5	4¼	2	6
7	30	„	2	1¼	3	3¼	4	1⅝	4	9⅝	5	2⅝	5	4⅛	5	3¼	2	0
8	0	„	1	11¼	3	1¼	4	0⅝	4	8⅝	5	2¼	5	3⅛	5	2¼	1	9
8	30	„	1	9¼	2	11¼	3	11⅝	4	7⅝	5	0⅝	5	2⅛	5	1⅛	1	6
9	0	„	1	11¼	2	10¼	3	9⅝	4	6⅝	4	11¼	5	1¼	5	0¼	1	7
9	30	„	2	4¼	2	11¼	3	8⅝	4	5⅝	4	10¼	5	0¼	4	11¼	1	10
10	0	„	2	9¼	3	1¼	3	8⅝	4	4⅝	4	9¼	4	11¼	4	10¼	2	5
10	30	„	3	5½	3	5¼	3	7⅝	4	3⅝	4	8¼	4	10¼	4	9¼	2	11
11	0	„	4	0½	3	9½	3	9⅝	4	2⅝	4	7½	4	9⅛	4	8⅛	3	7
11	30	„	4	4½	3	11½	4	0⅝	4	2⅝	4	6½	4	8	4	7½	4	0
12	0	„	4	6½	4	1½	4	2⅝	4	3⅝	4	6½	4	7⅛	4	6½	4	3
0	30	p.m.	4	8½	4	4½	4	3⅝	4	5⅝	4	5⅝	4	6⅛	4	5⅝	4	6
1	0	„	4	10½	4	6½	4	5⅝	4	6⅝	4	6⅝	4	6	4	6	4	9
1	30	„	4	11½	4	7½	4	6⅝	4	7⅝	4	7½	4	6	4	7	5	0
2	0	„	5	0½	4	8½	4	7⅝	4	8⅝	4	8½	4	6⅝	4	8	5	3
2	30	„	5	0½	4	8½	4	8⅝	4	9⅝	4	9½	4	7⅝	4	9	5	5
3	0	„	4	11½	4	8½	4	8⅝	4	10⅝	4	10½	4	9	4	10	5	6
3	30	„	4	9½	4	7½	4	9⅝	4	11⅝	4	11½	4	10½	4	11	5	4
4	0	„	4	3½	4	5½	4	8⅝	4	11⅝	5	0½	4	10⅛	5	0	4	11
4	30	„	3	9½	4	3½	4	6⅝	5	0⅝	5	0⅝	5	0	5	0⅝	4	5
5	0	„	3	3½	3	11½	4	2⅝	4	11⅝	5	1½	5	1	5	1½	4	0
5	30	„	2	10½	3	8½	4	2⅝	4	10⅝	5	1½	5	1½	5	1⅝	3	7
6	0	„	2	5½	3	4½	4	1⅝	4	9½	5	0½	5	1½	5	0½	3	0

TIDES OF THE WAVENEY.

TABLE OF THE RISE AND FALL OF THE TIDE

At various points, taken simultaneously from the mouth of the river at Yarmouth to Beccles and at Lowestoft.

Datum line 5 feet below Old Zero at Mutford Bridge.

SPRING TIDE, March 29th, 1850.

Time.			Yarmouth Pier.		Yarmouth Bridge.		Burgh Flats.		St. Olave's.		Burgh St. Peter's.		Beccles		Mutford Lock, N. Side.		Lowestoft Pier.	
H.	M.		Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
6	0	a.m	2	6¼	2	3¼	3	1¾	3	11¾	4	5¼	4	6⅛	4	5¾	1	6
6	30	"	3	11¼	3	6¼	3	1¾	3	11¼	4	4¼	4	5⅜	4	4¾	3	0
7	0	"	4	7¼	4	0¼	3	4¾	3	10¾	4	3¼	4	4⅜	4	3¼	3	10
7	30	"	5	0¾	4	4¼	3	9¼	4	0¾	4	2¼	4	3⅛	4	2¼	4	4
8	0	"	5	3¼	4	7¼	4	0¼	4	2¼	4	1¼	4	2⅜	4	1¼	4	8
8	30	"	5	5¼	4	9¼	4	2¾	4	3¾	4	2¼	4	1⅛	4	1¼	5	1
9	0	"	5	9¼	4	10¼	4	5¾	4	5¾	4	3¼	4	1	4	2¼	5	5
9	30	"	5	10½	5	0½	4	6½	4	6½	4	4½	4	1½	4	4	5	9
10	0	"	5	10¼	5	1¼	4	8¾	4	8⅝	4	5¾	4	3⅜	4	5¾	6	1
10	30	"	5	9¼	5	1¼	4	9¾	4	10¾	4	7¼	4	5⅛	4	7	6	5
11	0	"	5	7¼	5	1¼	4	11¾	4	11¾	4	8¾	4	7⅜	4	8⅛	6	3
11	30	"	5	0¼	5	0¼	5	0¾	5	1¾	4	10¼	4	9⅛	4	9¾	5	9
12	0	"	4	3¼	4	9¼	5	0¾	5	2⅝	5	0¼	4	10¾	4	11½	5	0
0	30	p.m.	3	2¼	4	2½	5	0¼	5	3¼	5	1¼	4	11¾	5	1	4	1
1	0	"	2	6¼	3	9¼	4	7¾	5	1¼	5	1¾	5	0⅛	5	2	3	11
1	30	"	2	1¼	3	6¼	4	5¼	4	11¼	5	1¾	5	1⅞	5	2⅛	2	9
2	0	"	1	7¼	3	3¼	4	2¾	4	9¾	5	1¼	5	2¾	5	2	1	11
2	30	"	1	1¼	2	11¼	4	0¾	4	8¼	5	0¾	5	2⅛	5	1	1	5
3	0	"	0	8¼	2	7¼	3	10¾	4	6¾	4	11¼	5	1⅛	4	11¾	0	10
3	30	"	0	4¼	2	4¼	3	9¾	4	5¾	4	10¼	5	0⅛	4	10	0	1
4	0	"	0	2¼	2	2¼	3	7¾	4	4¾	4	8¾	4	11⅛	4	9¼	below zero 0	3
4	30	"	0	1¼	2	0¼	3	6¾	4	3¾	4	7¾	4	10¼	4	8¼	0	7
5	0	"	0	3¼	1	11¼	3	5¾	4	1¾	4	6¾	4	9	4	7	0	3
5	30	"	0	2¼	1	11¼	3	4¾	4	0¾	4	5¾	4	8	4	6	0	0
6	0	"	0	3¼	2	1¼	3	3¾	3	11¾	4	4¼	4	6¾	4	4¾	above 1	8

TIDES OF THE WAVENEY.

TABLE OF VELOCITIES OF THE HEAD AND FOOT OF TIDAL WAVE,

From Yarmouth Pier to Beccles Bridge, and to Lowestoft, at a Spring and Neap Tide.

NEAP TIDE, March 21st, 1850.

Names of Stations.	Distances apart.	Tidal Range	Interval of Passage of Foot of Wave	Interval of Passage of Head of Wave	Rate per Minute. Foot.	Rate per Minute. Head.
Between	Feet.	Ft. In.	H. M.	H. M.	Feet.	Feet.
Yarmouth Pier and Yarmouth Bridge ...	13,860	3 3	0 30	0 30	462	462
Yarmouth Bridge and Burgh Flats.........	20,988	1 10	1 30	0 30	233	700
Burgh Flats and St. Olave's	26,070	1 2	0 30	1 0	869	434.5
St. Olave's and Burgh St. Peter's............	29,436	0 10	1 30	0 30	327	981.2
Burgh St. Peter's and Beccles	34,980	0 7½	0 30	1 30	116.6	388.7
Yarmouth Pier and Beccles	**125,334**	**B 11½**	**4 30**	**4 0**	**464.2**	**522.8**
Yarmouth Pier and Lowestoft	38,148	4 0	..	0 30	..	1271.6

SPRING TIDE, March 29th, 1850.

Names of Stations.	Distances apart.	Tidal Range	Interval of Passage of Foot of Wave	Interval of Passage of Head of Wave	Rate per Minute. Foot	Rate per Minute. Head.
Between	Feet.	Ft. In.	H. M.	H. M.	Feet.	Feet.
Yarmouth Pier and Yarmouth Bridge ...	13,860	5 9	0 30	1 0	462	231
Yarmouth Bridge and Burgh Flats.........	20,988	3 2	1 30	1 0	462	349.8
Burgh Flats and St. Olave's	26,070	1 11	1 0	1 0	434.5	434.5
St. Olave's and Burgh St. Peter's............	29,436	1 4¼	1 0	0 30	491.6	981.2
Burgh St. Peter's and Beccles	34,980	1 0¼	1 0	1 0	583	583
Yarmouth Pier and Beccles	**125,334**	**1 1¼**	**5 0**	**4 30**	**417.8**	**464.2**
Yarmouth Pier and Lowestoft	38,148	7 0	..	1 0	..	635.8

TIDES OF THE NENE.

TIMES AND HEIGHTS OF HIGH AND LOW WATER, AT SPRING AND NEAP TIDES,

With Sectional Area, Width and Depth at each place.

From observations taken under the direction of J. M. Rendel, Esq., F.R.S.

Datum Cill of the North Level Sluice.

Stations and Sections of River at High Water, April 17th, 1851.	Distances.	Spring Tide, April 17, 1851.				Neap Tide, April 24, 1851.			
		High Water.		Low Water.		High Water.		Low Water.	
		Time.	Height	Time.	Height	Time.	Height	Time.	Height
Area. Sq.Ft. Wdth. Ft. Dpth. Ft.	Feet.	H. M. a.m.	Ft. In.	H. M. a.m.	Ft. In.	H. M. p.m.	Ft. In.	H. M. a.m.	Ft. In.
Horseshoe	..	8 15	20 0	5 30	5 3	0 55	13 0	9 0	5 6
Phillips' Brewery 1563 120 × 19	6,600	8 20	19 6	5 20	8 6	1 5	12 9	9 45	7 7
Waldersea Sluice 1464 112 × 23	12,540	8 50	19 1	6 0	11 1	2 10	13 0	10 30	9 11
Guyhirn............ 1432 140 × 14	16,500	9 20	18 9	7 15	13 6	1 55	14 2	p.m. 0 10	11 9
Cross Guns ...... 421 57 × 12	17,160	10 0	16 9	8 0	14 10	3 15	13 9	1 20	13 3
Dog and Doublet 736 82 × 8	25,080	11 5	16 6	9 5	16 5	4 20	15 3	2 20	15 2
Peterborough ... 500 60 × 9	27,720	p.m. 1 5	16 5	11 0	16 7	6 20	16 0	4 20	16 0
	105,600								

INCLINATION OF RIVER SURFACE AT TIMES OF HIGH AND LOW WATER AT WISBEACH.

Stations and Sections of River at Low Water, April 17th, 1851.	Distances.	Spring Tide, April 17, 1851.				Neap Tide, April 24, 1851.			
		Height on Gauge.		Inclination ℔ Mile.		Height on Gauge.		Inclination ℔ Mile.	
		At H. W.	At L. W.	At H. W. Fall.	At L. W. Rise.	At H. W.	At L. W.	At H. W. Fall.	At L. W. Rise.
Area. Sq.Ft. Wdth. Ft. Dpth. Ft.	Feet.	Ft. In.	Ft. In.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Horseshoe	..	20 0	5 3	..	..	13 0	5 6	..	..
Wisbeach Bridge	4,620	19 10	7 1	.185	2.091	12 10	6 7	.185	1.234
Phillips' Brewery 469 80 × 8	1,980	19 5	8 5	1.120	3.547	12 7	7 8	.666	2.880
Waldersea Sluice 709 78 × 15	12,540	18 6	11 2	.387	1.157	12 0½	10 0	.227	.981
Guyhirn............ 678 130 × 9	16,500	17 0	14 3	.480	.985	12 11	12 11	Rise. .281	.934
Cross Guns ...... 317 45 × 10	17,160	16 1½	15 0	.270	.230	13 2	13 2	.077	.077
Dog and Doublet 730 82 × 8	25,080	16 3	16 3	Rise. .025	.263	15 1	15 1	.400	.400
Peterborough ... 500 60 × 9	27,720	16 7	16 7	.063	.063	15 6	15 6	.080	.080
Average.........	105,600			.171	.566			.125	.500

TIDES OF THE HUMBER,

AT GREAT GRIMSBY.

TABLE SHEWING THE RISE AND FALL OF A SPRING & NEAP TIDE,

Together with the Tidal Range, and Semi-diurnal Inequality for three successive days of Spring and Neap Tides.

Datum Line 4 feet above Cill of 70 feet Lock.

SPRING TIDES.

Oct. 5, 1846. Time. H. M.	Hght. ft. ins.
a.m. 5 0	H. W. 24 7
5 30	24 0
6 0	23 0
6 30	21 6
7 0	20 3
7 30	18 6
8 0	16 5
8 30	13 9
9 0	11 3
9 30	8 9
10 0	7 0
10 30	4 9
11 0	3 3
11 30	2 0
12 0	1 4½
p.m. 0 15	L. W. 1 3
1 0	2 6
1 30	4 3
2 0	6 3
2 30	9 3
3 0	12 2
3 30	14 9
4 0	17 4
4 30	19 8
5 0	21 6
5 30	22 4
5 48	H. W. 22 8

Date. 1846.	Moon's age at noon. days.	High Water. Time. H. M.	High Water. Height on Gauge. ft. ins.	Low Water. Time. H. M.	Low Water. Height on Gauge. ft. ins.	High Water. Time. H. M.	High Water. Height on Gauge. ft. ins.	Tidal Range. a.m. ft. ins.	Tidal Range. p.m. ft. ins.	Semi-diurnal in-equality. ft. ins.
October 4th	14	5 0 a.m.	23 4	11 10 a.m.	1 9	5 0 p.m.	22 4	21 7	20 7	1 0
" 5th	15	5 0	24 7	0 15 p.m.	1 3	5 45	22 7	23 4	21 4	2 0
" 6th	16	5 45	24 6	0 30	1 0	6 20	22 1	24 6	22 1	2 5

NEAP TIDES.

Oct. 14, 1846. Time. H. M.	Hght. ft. ins.
a.m. 7 0	L. W. 6 6
7 30	6 9
8 0	7 3
8 30	8 0
9 0	8 9
9 30	9 8
10 0	10 8
10 30	12 0
11 0	13 0
11 30	13 10
12 0	14 8
p.m. 0 30	15 4
1 0	15 9
1 30	H. W. 15 10
2 0	15 9
2 30	15 5
3 0	14 10
3 30	14 3
4 0	13 3
4 30	12 3
5 0	11 1
5 30	10 4
6 0	9 6
6 30	9 0
6 40	L. W. 8 11

Date. 1846.	Moon's age at noon. days.	High Water. Time. H. M.	High Water. Height on Gauge. ft. ins.	Low Water. Time. H. M.	Low Water. Height on Gauge. ft. ins.	High Water. Time. H. M.	High Water. Height on Gauge. ft. ins.	Tidal Range. a.m. ft. ins.	Tidal Range. p.m. ft. ins.	Semi-diurnal in-equality. ft. ins.
September 13th	23	11 15 a.m.	17 8	5 0 p.m.	7 10	11 30 p.m.	18 3	9 10	10 5	0 7
October 14th	24	Low 7 0	Water. 6 6	High 1 30	Water. 15 10	Low 6 40	Water. 8 11	9 4	6 11	2 5
November 12th	25	6 30	7 4	0 30	16 7	6 30	8 7	9 3	8 0	1 3

TIDES OF THE TAY.

RESULTS OF TIDAL OBSERVATIONS,

Made at various times between 1833 and 1844, by Messrs. Stevenson of Edinburgh, shewing the results of the improvements in the river, by dredging, &c.

Stations.	Distance.	1833 & 1834.		1842, 1843, and 1844.		Improvemnt.	
		Diff. of H. W.	Vel. of Tidal Wave per Min.	Diff. of H. W.	Vel. of Tidal Wave per Min.	Time.	Velocity per Minute.
	Feet.	Mins	Feet.	Mins.	Feet.	Mins.	Feet.
Between							
Dundee and Balmerino......	26,400	16	1,650	same as in the years 1833 and 1834			
Balmerino and Flisk Point	15,470	29	533.4				
Flisk Point and Balmbreich	10,771	26	414.3				
Balmbreich and Newburgh	18,058	53	340.7				
Newburgh (*a*) and Perth (*b*)	45,197	150	301.3	100	452	50	150.7
Dundee and Perth	115,896	274	422.9	224	517.4	50	94.5
Newburgh (*a*) and Carpon...	7,022	not observed in 1834		25	281.		
Carpon and Kinfauns.........	25,925			55	462.3		
Kinfauns and Perth (*b*)......	12,250			20	612.5		

LEVELS OF HIGH WATER SURFACE.

The levels of the surface of high water, at different stations, have been found to be unchanged, and the following results refer to the years 1833 and 1844.

Stations.	Distances.	Spring Tide, 1833 & 1844.			Neap Tide, 1833 & 1844.		
		Rise.	Fall.	Rate per Mile.	Rise.	Fall.	Rate per Mile.
Between	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Flisk Point and Balmbreich	10,771	..	.42	.206	..	21	.103
Balmbreich and Newburgh	18,058	.62	..	.181	.50	..	.145
Newburgh and Perth.........	45,197	1.00	..	.117	1.00	..	.117

LEVELS OF LOW WATER SURFACE.

Stations.	Distances.	Spring Tide, 1833.		Spring Tide. 1844.	
		Rise.	Rate per Mile.	Rise.	Rate per Mile.
Between	Feet.	Feet.	Feet.	Feet.	Feet.
Flisk Point and Balmbreich ...	10,771	.33	.161	.33	.161
Balmbreich and Newburgh	18,058	2.66	1.304	2.66	1.304
Newburgh and Perth...............	45,197	4.00	.467	2.00	.233

Note.—The result of the observations in 1844, gives a depression on the level of low water mark of 2 feet, at Perth *tidal harbour*, the point to which Perth observations refer.

TIDES OF THE TYNE.

TABLE OF THE RISE AND FALL OF THE TIDE,

At various points, taken simultaneously from the mouth of the river to Newburn, under the direction of J. M. Rendel, Esq., F.R.S.

Zero is the mark at Prior's Stone, being Low Water of May 31st, 1818.

SPRING TIDE, May 8th, 1850.

Time.	Prior's Stone.	Ballast Office.	Howdon.	Bill Point.	Old Quay.	Elswick.	Stella.	Newburn.
H. M.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.
10 30 a.m.	0 10LW	10 45 a.m. 1 3LW						
11 0 "	1 2	1 5	11 15 1 10LW					
11 30 "	2 1	2 0	1 11					
12 0 "	3 2	3 3	2 11	12 15 p.m. 3 2LW				
0 30 p.m.	4 6	4 6	4 2	3 5	12 45 3 4LW			
1 0 "	6 2	6 2	5 6	4 4	3 11			
1 30 "	8 0	7 9	7 1½	5 6	4 11	1 45 5 4LW		
2 0 "	9 10	9 6	8 9	7 3	6 4½	5 8		
2 30 "	11 2	10 10	10 3	9 0	8 1½	6 10		
3 0 "	12 2	12 0	11 6	10 7	9 7½	8 0½	3 15 8 0½LW	
3 30 "	12 9	12 8	12 5	11 9	10 11	9 6	8 2	
4 0 "	13 2	13 2	13 0	12 8	12 0	10 10	9 0½	
4 30 "	13 2	13 0	13 4HW	13 1½	12 9	12 0	10 11	11 1LW
5 0 "	12 8	12 10	13 0	13 3HW	13 1	12 10½	11 5	12 3
5 30 "	11 10	12 3	12 2½	12 9	13 2	13 4½	13 6	13 6
6 0 "	10 11	11 3	11 1	12 2	12 9	13 2	13 7½	13 9
6 30 "	9 8	10 2	10 2½	11 5	12 0	12 6	12 10	13 0
7 0 "	8 0	9 0	9 6	10 6	11 2	11 9	12 1	12 3
7 30 "	6 4	7 6	8 3	9 6	10 3	11 0	11 5	11 9
8 0 "	4 10	6 0	7 0	8 5	9 4	10 3	10 9	11 3
8 30 "	3 7	4 8	5 10	7 6	8 6	9 6	10 2	11 1
9 0 "	2 7	3 7	4 9	6 8½	7 8	8 11	9 9	11 0½
9 30 "	1 8	2 7	3 10	6 0	7 0	8 3	9 3	
10 0 "	1 1	1 9	3 0	5 3	6 3	7 9	8 11	
10 30 "	0 11LW	1 5	2 5	4 9	5 7½	7 5	8 8	
11 0 "	..	1 2LW	1 11	4 3	5 0	7 0	8 6	
11 30 "	..	..	1 9LW	3 9	4 6	6 7	8 4	
12 0 "	..	..	..	3 5	4 0	6 3	8 3	
0 30 a.m.	..	..	..	3 2LW	3 7	5 11	8 2	
1 0 "	..	..	..	..	3 5LW	5 7½	8 1½	
1 30 "	..	..	..	..	..	5 5½	8 1	
1 50 "	..	..	..	..	..	5 4½LW	8 0½LW	
4 15 "	..	13 3HW						
5 15 "	..	..	..	..	13 4HW			
5 45 "	..	..	..	..	..	..	13 9HW	13 10HW

TIDES OF THE TYNE.

TABLE OF THE RISE AND FALL OF THE TIDE,

At various points, taken simultaneously from the mouth of the river to Newburn, under the direction of J. M. Rendel, Esq., F.R.S.

Zero is the mark at Prior's Stone, being Low Water of May 31st, 1818.

NEAP TIDE, April 2nd, 1849.

Time.	Prior's Stone.	Ballast Office.	Howdon.	Bill Point.	Old Quay.	Elswick.	Stella.	Newburn.
H. M.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.
4 45 a.m.	3 9	4 0	4 5					
5 0 „	3 8LW	3 11LW	4 3					
5 30 „	3 10	3 11½	4 0½LW					
6 0 „	4 2	4 2	4 1½	4 8½				
6 30 „	4 6	4 7	4 6½	4 9				
7 0 „	5 0	5 4	5 1	5 1	5 1½LW			
7 30 „	5 9	6 0	5 8½	5 6	5 3			
8 0 „	6 8	7 0	6 7½	6 2	6 0	7 2LW		
8 30 „	7 7	7 10	7 6	7 1	6 11	7 3		
9 0 „	8 6	8 10	8 5½	8 0	7 8½	7 8	9 45	
9 30 „	..	9 8	9 3	9 0	8 7	8 5½	9 9LW	
10 0 „	..	10 4	10 2	9 10	9 4	9 2	9 10	
10 30 „	11 2HW	10 10	10 8½	10 7	10 3	9 11	10 4	11 15
11 0 „	..	11 2HW	11 1½	11 2	10 11	10 8	11 0	12 7
11 30 „	..	11 2	11 5HW	11 6½	11 5	11 4	11 7	12 7¾
12 0 „	..	11 0	11 2½	11 8½HW	11 7	11 10	12 0	12 10
0 30 p.m.	..	10 7	10 10	11 7	11 8	11 10HW	12 1	12 11HW
1 0 „	..	10 0	10 4	11 0	11 2	11 7	11 10½	12 10
1 30 „	..	9 2	9 6	10 4	10 7	11 1	11 7	12 9
2 0 „	..	8 3	8 8	9 7	10 0	10 7	11 3	12 8
2 30 „	..	7 4	7 10	8 10	9 3½	10 1	10 11	12 6¾
3 0 „	..	6 6	6 11½	8 2	8 7½	9 7	10 7	12 5½
3 30 „	4 11	5 6	6 1	7 6	8 0	9 1	10 3½	12 4
4 0 „	4 2	4 10	5 4	6 10	7 5	8 8	10 0	12 3
4 30 „	3 6	3 10	4 8	6 3	6 11	8 3½	9 10½	12 2½
5 0 „	2 11	3 5	4 1	5 9	6 4	7 11	9 8¾	
5 30 „	2 8LW	3 0	3 7½	5 3	5 9	7 7	9 7½	
6 0 „	..	2 11LW	3 3½	4 10	5 5	7 3½	9 6½	
6 30 „	..	..	3 2LW	4 4	5 0	7 1	9 5¾	
7 0 „	..	..	..	4 2	4 7½	6 11	9 5LW	
7 30 „	..	..	..	..	4 4	6 9		
8 0 „	..	..	..	..	4 2LW	6 7		
8 30 „	..	..	..	..	..	6 6LW		
12 15 p.m.	..	..	..	..	11 8½HW	..	12 1½HW	
4 45 „	..	..	..	..	..	..	..	12 2LW
7 15 „	..	..	..	4 1LW				

TIDES OF THE TYNE.

VELOCITIES OF THE HEAD AND FOOT OF A TIDAL WAVE,

At a Spring and Neap Tide, from the mouth of the river to Newburn.

From observations taken under the direction of J. M. Rendel, Esq., F.R.S.

SPRING TIDE, May 8th, 1850, one day after Full Moon.

Names of Stations.	Distances.	Tidal Range.		Interval of Passage of		Rate per Minute.	
				Foot of Wave	Head of Wave	Foot.	Head.
Between	Feet.	Ft.	In.	Mins.	Mins.	Ft.	Ft.
Tynemouth Haven and Prior's Stone...	2,640	12	7 T H	..	15	..	176.0
Prior's Stone and Ballast Office	3,894	12	4 P S	15	15	259.6	259.6
Ballast Office and Howdon..................	13,200	12	0 B O	30	15	440.0	880.0
Howdon and Bill Point	20,064	11	6 H	60	25	334.4	802.6
Bill Point and Old Quay......................	15,576	10	1 B P	30	20	519.2	778.8
Old Quay and Elswick	12,804	10	0 O Q	60	15	213.4	853.6
Elswick and Stella	18,942	8	0½ E	90	..	210.5	..
Stella and Newburn	7,524	5	8½ St.	75	15	100.3	501.6
Tynemouth and Newburn	94,644	2	9 N	360	120	262.9	788.7

NEAP TIDE, April 2nd, 1849.

Names of Stations.	Distances.	Tidal Range.		Interval of Passage of		Rate per Minute.	
				Foot of Wave	Head of Wave	Foot.	Head.
Between	Feet.	Ft.	In.	Mins.	Mins.	Ft.	Ft.
Tynemouth Haven and Prior's Stone..	2,640	7	6 T H	15	15	176.0	176.0
Prior's Stone and Ballast Office	3,894	7	6 P S	15	15	259.6	259.6
Ballast Office and Howdon..................	13,200	7	3 B O	30	30	440.0	440.0
Howdon and Bill Point	20,064	7	4½ H	40	30	501.5	668.8
Bill Point and Old Quay......................	15,576	7	0 B P	30	15	519.2	1038.4
Old Quay and Elswick	12,804	6	7 O Q	80	..	160.5	..
Elswick and Stella	18,942	4	8 E	90	..	210.5	..
Stella and Newburn	7,524	2	4 St.	90	15	83.6	501.6
Tynemouth and Newburn	94,644	0	8½ N	390	120	242.7	788.7

TIDES OF THE TYNE.

INCLINATION OF WATER SURFACE

At the times of High and Low Water, at Tynemouth Haven and at Newburn, with Fall of River Bed, Sectional Area, &c.

Zero is the Mark at Prior's Stone, being Low Water of May 31st, 1813.

SPRING TIDE, May 8th, 1850.

When High and Low Water at Tynemouth Haven.	Distances.	Height on Gauge. At H. W.		Height on Gauge. At L. W.		Average Inclination per Mile. At H.W. Fall.	Average Inclination per Mile. At L.W. Rise.	Area, &c. at High Water. Area.	Greatest Wdth.	Greatest Dpth.
	Feet.	Ft.	In.	Ft.	In.	Feet.	Feet.	Sq. Ft.	Feet.	Feet.
Tynemouth Haven...	..	13	4	0	8					
Prior's Stone...........	2,640	13	2	0	11	.333	.500			
Ballast Office	3,894	13	2	1	5	..	.686			
Howdon	13,200	13	0	2	5	.064	.400	24,500	1,550	25
Bill Point	20,064	12	8	4	9	.087	.613	10,770	750	25
Old Quay	15,576	12	0	5	7½	.230	.295	6,935	363	22
Mansion House	1,386	11	11	5	11	.316	1.115	7,000	560	13
Elswick	11,418	10	10	7	5	.500	.696	6,270	660	13
Stella	18,942	9	0½	8	8	.500	.349	1,800	300	13
Newburn	7,524	11	1	11	0½	Rise. 1.436	1.670	1,300	320	5
Average..........	94,644	..		..		..	.579			
	Average fall to Stella					.259				

When High and Low Water at Newburn.	Distances.	Height on Gauge. At H. W.		Height on Gauge. At L. W.		Average Inclination per Mile. At H.W. Fall.	Average Inclination per Mile. At L.W. Rise.	Area, &c. at Low Water. Area.	Greatest Wdth.	Greatest Dpth.
	Feet.	Ft.	In.	Ft.	In.	Feet.	Feet.	Sq. Ft.	Feet.	Feet.
Newburn	..	13	9	11	0½	..	..	100	200	2.25
Stella	7,524	13	7½	9	9	.084	.905	360	150	7.33
Elswick	18,942	13	2	8	11	.128	.232	600	300	5.0
Mansion House	11,418	12	11	7	11	.115	.463	1,000	530	3.25
Old Quay	1,386	12	9	7	8	.615	.961	2,770	363	11.0
Bill Point	15,576	12	2	6	8½	.196	.326	2,874	400	15.0
Howdon	20,064	11	1	4	9	.284	.516	5,500	1,100	13.50
Ballast Office	13,200	11	3	3	7	Rise. .064	.464			
Prior's Stone...........	3,894	10	11	2	7	Fall. .452	1.356			
Tynemouth Haven...	2,640	10	6	2	0	.833	1.166			
Average..........	94,644	..		..		.181	.504			

TIDES OF THE CLYDE.

TABLE OF TIDAL OBSERVATIONS,

Taken simultaneously between Port Glasgow and Glasgow, in 1840; shewing also the acceleration in the time of high water.

Datum, 20 feet below coping of South Quay Wall, near Glasgow Bridge.

SPRING TIDE, 20th March, 1840.

Time.	Port Glsgow	Bowling.	Clyde Bank.	Glsgow
H. M.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
A.M. 8 0	1 8			
9 0	3 9	2 10		
10 0	5 0	4 3	3 8	3 0LW
11 0	6 9½	5 4	4 9	4 8
12 0	8 8½	6 11	6 1½	6 0½
P.M. 1 0	10 3½	9 2½	7 10	7 9
2 0	10 1	10 10	10 0½	9 10½
3 10	7 11	9 5	10 7	11 1½HW
4 10	5 4	8 1	9 4	9 8½
5 10	3 4	6 10	8 0	8 3
6 10	1 4	5 7½	6 8½	7 0
7 10	0 2½	4 2	5 7	5 10½
8 10	..	2 11	4 5½	4 9
9 10	..	..	3 4	3 9
A.M. 7 10	0 2⅝LW			
8 38	..	2 4LW		
9 30	..	..	3 1LW	
P.M. 1 25	10 5½HW			
2 5	..	10 10HW		
2 50	..	..	10 10HW	

NEAP TIDE, 27th March, 1840.

Stations.	High W.	Low W.	Range.	Remarks
	Ft. In.	Ft. In.	Ft. In.	
Pt. Glasgow	7 5	2 4	5 1	H. W. at Glasgow 6" higher than Port Glasgow.
Bowling......	7 9	2 6	5 3	
Clyde Bank	7 11	2 8	5 3	L. W. at Glasgow 3" higher than Port Glasgow.
Glasgow.....	7 11	2 7	5 4	

High Water of Spring Tide,

24th December, 1839,

With Fresh Wind, West.

	Ft. In.		Ft. In.
Port Glasgow...	14 5	Clyde Bank......	15 6
Bowling	15 0	Glasgow	16 2

Note.—High Water at Glasgow 1.9" higher than at Port Glasgow.

	H. M.
Note.—In 1824, H. W. at Glasgow later than at Port Glasgow.........	2 05
In 1840, ditto	1 45
Acceleration in 16 years.........	0 20

Velocities of Flood and Ebb Streams.

STATIONS.	Rate ℔ M. Fld.	Rate ℔ M. Ebb.
Between	Feet	Feet.
Glasgow and Newshot Isle	38.5	78.8
Newshot I. and Dumbarton Castle	80.1	139.3

VELOCITIES OF THE HEAD AND FOOT OF A TIDAL WAVE,

Between Port Glasgow and Glasgow.

SPRING TIDE, 20th, March, 1840.

STATIONS.	Distances Apart.	Tidal Range	Interval of Passage of Foot of Wave.	Interval of Passage of Head of Wave.	Rate per Minute. Foot.	Rate per Minute. Head.	Width of River in 1846.
Between	Feet.	Ft. In.	Mins.	Mins.	Feet.	Feet.	Feet.
Port Glasgow and Bowling	43,230	10 2⅝PtG	88	40	491.2	1080.7	550 B
Bowling and Clyde Bank	26,290	8 6B	52	45	505.6	584.2	250 CB
Clyde Bank and Glasgow	28,820	7 9CB	30	20	960.6	1,441	420G
Port Glasgow & Glasgow	98,340	8 1½ G	170	105	578.5	936.6	

TIDES OF THE CLYDE.

INCLINATION OF WATER SURFACE,

At the times of High and Low Water at Port Glasgow and Glasgow, at the Spring Tide of March 20th, 1840.

Datum 20 feet below Coping of South Quay Wall.

WHEN HIGH WATER AT PORT GLASGOW - - 1.25 p.m.
AND LOW WATER „ „ - - 7.20 „

STATIONS.	Distances.	Height on Gauge.		Inclin. per Mile.	
		At 1.0 p.m. or 25 minutes before H. W.	At 7.10 p.m. or 10 minutes before L. W	At 1.0 p.m. or 25 minutes before H. W Fall.	At 7.10 p.m. or 10 minutes before L W Rise.
	Feet.	Ft. In.	Ft. In.	Feet.	Feet.
Port Glasgow	..	10. 3½	0 2¼	..	..
Bowling	43,230	9. 2¼	4 2	0. 132	0.483
Clyde Bank	26,290	7. 10	5 7	0. 279	0. 285
Glasgow	28,820	7. 9	5 10½	0. 014	0. 053
Average	98,340			0.136	0.304

WHEN HIGH WATER AT GLASGOW - - - - - 3.10 p.m.
AND LOW WATER „ „ - - - - - 10. 0 a.m.

STATIONS.	Distances.	Height on Gauge.		Inclin. per Mile.	
		At High Water. Fall.	At Low Water. Rise.	At High Water. Fall.	At Low Water. Rise.
	Feet.	Ft. In.	Ft. In.	Feet.	Feet.
Glasgow	..	11 1½	3 0	..	..
Clyde Bank	28,820	10 7	3 8	0.099	0. 122
Bowling	26,290	9 5	4 3	0.233	0. 116
Port Glasgow	43,230	7 11	5 0	0. 183	0. 092
Average	98,340			0.171	0.107

SECTIONAL AREAS.

Spring Tide, March 20th, 1840.	At High Water.			At Low Water.		
	Area.	Greatest Width.	Greatest Depth	Area.	Greatest Width.	Greatest Depth.
	Sq. Feet.	Feet.	Ft. Ins.	Sq. Feet.	Feet.	Ft. Ins.
Glasgow	3, 148	198	18. 3	1, 549	191	10 0
Clyde Bank	4, 005	273	17. 0	1,911	245	9. 0
Neap Tide, March 27th, 1840.						
Glasgow	2, 524	195	15. 7	1, 494	191	10. 3
Clyde Bank	3, 186	255	14. 6	1, 840	245	9. 3

TIDES OF THE CLYDE.

MEAN TIDAL RANGE AND DURATION OF FLOOD AND EBB STREAMS,

For six Spring and six Neap Tides, from observations by W. Bald, Esq.

Spring Tides.	Glasgow.		Clyde Bank.		Bowling.		Port Glasgow.	
	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
Tidal Range	8	4	8	0	8	9	10	5
	H.	M.	H.	M.	H.	M.	H.	M.
Duration of Flood	5	10	5	15	5	24	6	6
„ Ebb	7	13	7	6	6	56	6	1
Neap Tides.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
Tidal Range	6	3	5	10	5	11	6	1
	H.	M.	H.	M.	H.	M.	H.	M.
Duration of Flood	5	14	5	43	5	52	6	26
„ Ebb	7	16	7	1	6	37	5	59

MEAN VELOCITIES OF FLOOD AND EBB STREAMS.

Station opposite.	Distance below Glasgow Bridge.	Velocity of Flood per Minute.	Velocity of Ebb per Minute.
	Feet.	Feet.	Feet.
Dumbarton Castle	72,000	58.75	144.53
Dunglass Castle	59,500	92,73	145.71
Donald's Quay	52,000	114.43	147.13
Rushalee Pier	45,000	54.53	120.00
Centre of Newshot Isle	39,000	70.00	150.00
Average below Newshot Isle	..	**78.10**	**141.48**
1,000 yards below mouth of the Cart	31,000	60.00	100.00
Scotstoun House	24,000	26.66	85.70
200 yards below Crawford's Quay	15,000	50.00	75.00
600 yards above the mouth of the Kelvin	9,500	17.63	54.53
Average above Newshot Isle	..	**38.56**	**78.80**

During high floods, immediately below Glasgow Bridge, Mr. Bald found the Ebb Stream run at the rate of 256.6 feet per minute; and in the narrow parts of the river, at the rate of 321.4 feet per minute. This was at the water's surface, in the middle of the river.

TIDES OF THE MERSEY.

TABLE OF THE RISE AND FALL OF THE TIDE

At various points, taken simultaneously from the mouth of the river at Formby Point to the head of the tide at Warrington; from Mr. Rendel's experiments in the summer of 1844. Datum line 6 feet below Old Dock Cill, or 10.75 feet below the Ordnance half-tide datum.

SPRING TIDES, June 3rd, 1844.

TIME. Distance.	Formby Point.	New Brighton 42,240 ft.	Prince's Dock, Livrpool. 10,560 ft.	Ellesmere Port. 47,520 ft.	Duke's Dock, Runcorn. 35,200 ft.	Fiddlers' Ferry. 28,160 ft.	Warrington Bridge. 27,400 ft.
H. M.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
7 0 a.m.	— 3 10						
7 30 „	— 2 9	— 4 2	— 4 5				
8 0 „	— 0 10	— 3 2	— 3 5				
8 30 „	1 10	— 0 8	— 0 10				
9 0 „	5 6	3 6	2 10				
9 30 „	9 9	8 2	7 6				
10 0 „	14 0	12 7	11 9	6 4			
10 30 „	17 6	16 5	15 1½	10 7			
11 0 „	20 4	19 2	18 0	15 0	10 7		
11 30 „	22 2	21 5	20 6	18 3	16 9		
12 0 „	23 3	22 8	22 2	21 2	20 8		
0 30 p.m.	23 4	23 0	23 4	23 5	23 1	17 6	
1 0 „	22 6	22 8	23 7	24 7	24 11	22 6	18 1
1 30 „	21 2	21 4	22 7	24 2	25 4	24 9	18 3
2 0 „	19 4	19 6	20 7	22 9	24 1	25 2	23 0
2 30 „	16 11	16 8	17 7	20 11	22 3	24 0	25 9
3 0 „	14 0	13 9	14 7	18 3	20 0	22 6	23 10
3 30 „	10 11	11 0	11 10	15 9	18 3	21 8	22 8
4 0 „	8 2	8 4	9 4	13 4	16 3	20 8	21 10
4 30 „	5 4	5 10	6 10	10 7	14 5	19 10	21 1
5 0 „	2 9	3 8	4 4	8 6	13 1	19 4	20 8
5 30 „	0 9	1 7	2 0	7 2	12 3	18 10	20 2
6 0 „	— 0 10	0 0	0 4	6 7 L.W.	11 6	18 7	19 9
6 30 „	— 2 0	— 1 5	— 1 3	....	10 11	18 2	19 6
7 0 „	— 2 7	— 2 4	— 2 8	....	10 7	17 10	19 3
7 30 „	....	— 3 6	— 3 6	....	10 4	17 6	19 0

TIDES OF THE MERSEY.

TABLE OF THE RISE AND FALL OF THE TIDE

At various points, taken simultaneously from the mouth of the river at Formby Point to the head of the tide at Warrington; from Mr. Rendel's experiments in the summer of 1844. Datum line 6 feet below Old Dock Cill, or 10.75 feet below the Ordnance half-tide datum.

NEAP TIDES, June 10th, 1844.

TIME.	Formby Point.	New Brighton	Prince's Dock, Livrpool.	Ellesmere Port.	Duke's Dock, Runcorn.	Fiddlers' Ferry.	Warrington Bridge.
Distance.		42,240 ft.	10,560 ft.	47,520 ft.	35,200 ft.	28,160 ft.	27,400 ft.
H. M.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
1 30p.m.	3 3	2 6	2 9	1 11			
2 0 „	4 0	3 1	3 1	2 3			
2 30 „	5 2	4 0	4 1	3 0			
3 0 „	6 8	5 5	5 5	4 2			
3 30 „	8 4	7 3	7 3	*5 9			
4 0 „	10 2	9 4	9 3	7 2			
4 30 „	12 3	11 6	11 4	9 7	8 8		
5 0 „	14 3	13 6	13 4	11 10	8 9		
5 30 „	15 6	15 2	15 0	13 8	10 10		
6 0 „	16 10	16 3	16 3	15 5	13 6		
6 30 „	17 7	17 2	17 4	16 7	15 10		
7 0 „	17 9	17 7	18 0	17 7	17 4	16 1	
7 30 „	17 7	17 7	18 0	18 4	18 5	16 2	
				18 7 H.W.			
8 0 „	16 11	16 10	17 6	18 3	19 0	16 10	
8 30 „	15 9	15 11	16 4	17 5	18 6	18 3	18 1
9 0 „	14 9	14 4	15 1	16 2	17 5	18 10	18 1
9 30 „	13 2	12 9	13 6	14 4	16 4	18 2	18 5
10 0 „	12 3	11 0	11 6	12 8	15 2	17 9	18 9
10 30 „	9 9	9 5	10 0	10 9	13 10	17 4	18 8
11 0 „	8 3	7 11	8 5	9 1	12 9	17 1	18 6
11 30 „	6 3	6 4	6 11	7 9	12 0	16 10	18 5
12 0 „	5 4	5 0	5 6	6 8	11 3	16 8	18 4
0 30a.m.	4 4	3 10	4 3	*4 6	10 9	16 7	18 2
1 0 „	3 7	2 10	3 4	3 0	10 3	16 4½	18 1½
1 30 „	3 1 LW	2 6 LW	2 9 LW	2 0	9 4	16 3	18 1½

* Below these points the Ellesmere tide is taken at Pool Hall Deep, about a mile below where there is a full range at Neap Tides.

TIDES OF THE MERSEY.

TABLE OF VELOCITIES OF THE HEAD AND FOOT OF TIDAL WAVE,

From the mouth to the head of the Tide at Warrington, at a Spring and Neap Tide.

Section of River from Prince's Dock to Seacombe.

	Area. Sq. Ft.	Width. Ft.	Depth. Ft.		Area. Sq. Ft.	Width. Ft.	Depth. Ft.
L.W.S.T.	114,546 ...	3,214 ×	50	H.W.N.T.	182,771 ...	3,544 ×	70
L.W.N.T.	188,415 ...	3,300 ×	57	H.W.S.T.	208,579 ...	3,544 ×	77

SPRING TIDE, June 3rd, 1844.

Names of Stations.	Distance apart.	Tidal Rnge	Interval of Passage of Foot of Wave	Interval of Passage of Head of Wave	Rate per Minute of Tidal Wave. Foot of Wave.	Rate per Minute of Tidal Wave. Head of Wave.	Flood Stream
Between	Feet.	Feet.	Min.	Min.	Feet.	Feet.	Feet.
Formby Point and New Brighton...	42,240	27.5	50	20	845	2,112	
New Brighton and Princes Dock ...	10,560	27.2	6	10	1,760	1,056	401.4
Princes Dock and Ellesmere	47,520	28.0	140	20	340	2,376	336.6
Ellesmere and Runcorn	35,200	18.3	50	14	704	2,514	
Runcorn and Fiddler's Ferry	28,160	14.9	85	26	331	1,084	
Fiddler's Ferry and Warrington...	27,400	7.8	66	40	415	685	
Formby Point and Warrington	191,080	7.8	397	130	481	1,470	

NEAP TIDE, June 10th, 1844.

Names of Stations.	Distance apart.	Tidal Rnge	Interval of Passage of Foot of Wave	Interval of Passage of Head of Wave	Rate per Minute of Tidal Wave. Foot of Wave.	Rate per Minute of Tidal Wave. Head of Wave.	Flood Stream
Between	Feet.	Feet.	Min.	Min.	Feet.	Feet.	Feet.
Formby Point and New Brighton...	42,240	14.5	..	20	..	2,112	
New Brighton and Princes Dock ...	10,560	15.1	25	20	422	528	
Princes Dock and Ellesmere	47,520	15.3	..	35	..	1,358	
Ellesmere and Runcorn	35,200	16.8	190	15	185	2,347	
Runcorn and Fiddler's Ferry.........	28,160	10.4	150	54	188	525	
Fiddler's Ferry and Warrington ...	27,400	1.8	95	46	288	595	
Formby Point and Warrington	191,080	0.3	460	190	415	1,006	

TIDES OF THE DEE.

TABLE OF PHENOMENA BETWEEN GREENFIELD AND CHESTER,

Taken from Minutes of Admiralty inquiry at Chester, in 1849.

The zero of heights is L.W.S.T. opposite Greenfield, or 22.75 below zero of Chester standard, being about 13.5 feet below mean half-tide level at Liverpool.

FORCED SPRING TIDE, With Westerly Gale. FEBRUARY 6th, 1849.

Time.	Flint.		Con-nah's Quay.		Sandy Croft.		Chester	
H. M.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
	9	9LW						
9 0a.m.	11	0						
9 15 „	13	0						
9 30 „	15	10						
9 45 „	18	3						
			14	3LW				
10 0 „	20	6	14	6				
10 15 „	22	0	17	0				
10 30 „	23	4	19	8	16	0LW		
10 45 „	25	0	23	10	20	0		
11 0 „	26	4	24	10	22	9	17	9LW
11 15 „	27	10	26	7	24	7	20	6
11 30 „	29	5	28	3	26	8	22	9
	29	11HW						
11 45 „	29	6	30	0	28	9	27	4
			30	9HW				
12 0 „	29	0	30	6	31	3HW	30	9
0 15p.m.	28	3	29	6	31	0	31	5HW
0 30 „	27	6	29	0	30	0	31	0
0 45 „	26	4	28	1	29	4	30	5
1 0 „	25	3	27	3	28	4	29	7
1 15 „	24	3	26	4	27	6	29	0
1 30 „	23	4	25	5	26	10	28	1
1 45 „	22	4	24	6	25	10	27	4
2 0 „	21	3	23	7	25	0	26	8
2 15 „	20	0	22	7	24	6	26	0
2 30 „	19	0	21	6	23	4	25	2
2 45 „	17	8	20	6	22	9	24	5
3 0 „	16	7	19	8	21	9	23	10
3 15 „	15	7	18	11	20	10	23	2
3 30 „	14	7	18	0	20	4	22	6
3 45 „	14	0	17	6	19	9	22	0

SUMMER LOW WATER.

Stations.	Length	Fall per Mile.
Between	Feet.	Feet.
Greenfield and Pentre Rock	30,095	1.84
Pentre Rock and Con. Quay	15,575	1.42
Con. Quay and Sandy Croft	17,160	.31
Sandy Croft and Saltney..	17,250	.75
Saltney and Chester	7,040	.21

VELOCITY OF HEAD AND FOOT OF TIDAL WAVE,

From Flint to Chester.

Stations.	Lngth	Tidal Range	Interval of Passage of Foot of Wave.	Interval of Passage of Head of Wave.	Rate per Minute. Foot.	Rate per Minute. Head.
Between	Feet.	Ft. Ins.	Mins.	Mins.	Feet.	Feet.
Flint and Pentre Rock	4,925	20.2	20	5	246.2	985
Pentre Rock and Connah's Quay	15,575	18.10	45	10	346	1557.5
Connah's Quay and Sandy Croft	17,150	16.6	30	9	572	1906.6
Sandy Croft and Saltney	17,250	15.3	20	8	862.5	2156.2
Saltney and Chester	7,040	13.8	10	4	704	1760
Flint and Chester	61,950	18.8	125	36	495.6	1720.8

AUGUST 6th 1849.	Green-field.		Flint.		Pentre Rock.		Con-nah's Quay.		Sandy Croft.		Saltny.		Chester	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
High Water, Ord. Sp. Tde.	27	6	27	7	27	8	28	8	29	4	29	7	29	8
Low Water „ „ „	0	0	9	1	10	6	14	2	15	5	17	9	18	1
Tidal Range „ „ „	27	6	18	6	17	2	14	6	13	11	11	10	11	7

TIDES OF THE SEVERN.

TABLE SHEWING THE HEIGHTS OF HIGH AND LOW WATER.

At Springs and Neaps, and the times of Flood and High Water at the principal points between Portishead and Diglis Lock, (just below Worcester) from Capt. Beechey's survey, 1849.

Note.—The zero of the Tidal Heights is that called the Ordnance Datum or half-tide level at Liverpool, being 4.75 feet above the Old Dock Cill.

Stations.	Distance apart.	Spring Tide. Aug. 20, 1849.			Neap Tide. Aug. 13, 1849.			Time of Flood after making at Beachley Pier.		Time of H. W. after making at Beachley Pier.	
		H.W.	L.W.	Range	H.W.	L.W.	Range	Aug. 20th.	Aug. 13th.	Aug. 20th	Aug. 13th.
	Feet.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	H. M.	H. M.	H. M.	H. M.
Portishead....											
Beachley	58,000	23 6	19 1	42 7	..	..	..				
Sharpness	60,950	25 6	2 0	27 6	16 10	2 6	19 4	2 48	2 36	0 39	0 42
Hock Crib....	39,829	25 11	6 9	19 2	16 10	5 6	11 4	3 54	4 42	0 42	1 08
Newnham	19,552	25 9	9 11	15 10	17 5	8 10	8 7	4 29	5 28	1 10	1 34
Framilode....	24,800	26 9	16 1	10 8	17 7	15 1	2 6	4 46	6 38	1 23	2 03
Rosemary	21,000	26 11	17 6	9 5	17 7	16 8	0 11	5 32	7 20	1 36	2 44
Stonebench ..	23,650	25 7	18 2	7 5	..	..	..	6 00	..	2 8	..
Gloucester....	18,940	24 4	18 9	5 7	18 4	17 11	0 5	6 14	..	2 22	..
Haw Bridge ..	40,000	23 1	19 10	3 3	no	tide	felt	7 01	..	3 16	..
Mythe Bridge.	27,800	23 1	21 3	1 10	..	..	..	..	..	3 58	..
Upton Bridge .	29,770	23 5	22 1	1 4	..	..	..	8 12	..	4 16	..
Pixham	34,060	24 5	24 2	0 3	..	..	..	..	..	..	..
Diglis........	16,780	25 7	25 7	..	25 3	..	..	..	...	..	..

TABLE OF AVERAGE RATE OF THE CREST
Of the Tidal Wave and of the Bore,

From Beachley to Upton Bridge, where the latter phenomenon ceases.

SPRING TIDES.	Rate of Crest of Tidal Wave.	Rate of the Bore.
Between	Feet ₩ Min.	Feet ₩ Min.
Beachley and Sharpness	1,599	328
Sharpness and Newnham	1,944	511
Newnham and Framilode	1,900	713
Framilode and Rosemary	996	460
Rosemary and Stonebench	872	1,206
Stonebench and Haw Bridge	1,057	1,075
Haw Bridge and Mythe Bridge	728	} 713
Mythe Bridge and Upton Bridge	1,058	

TIDES OF THE SEVERN.

TABLE OF FALL AND SECTIONAL AREA OF SUMMER LOW WATER,

Between Portishead and Diglis, from Captain Beechey's Admiralty Survey.

Note.—The datum of the heights given is the Ordnance mean half-tide at Liverpool.

STATIONS.	Distances Apart.	Mean Fall of River Bed ℔ Mile.	Summer Low Water. 4″ on Sharpness Gauge, or 7′.9″ on Diglis Lock Gauge.				
			Height on Gauge.	Fall per Mile.	Area.	Greatest Width.	Greatest Depth.
	Feet.	Feet.	Feet.	Feet.	Sq. Ft.	Feet.	Feet.
Portishead ....(below datum)	..	..	20.31	..	..	..	..
Beachley ...... „	58,000	..	18.90	.013	50,000	3370	46. 0
Inward Point .. „	16,750	1.86	17.55	.425	6,840	2730	5.25
Lidney .... „	36,500	1.98	3.87	1.98	1,230	630	3. 0
Sharpness ...... „	7,700	1.64	2.79	.74	4,176	1370	11.25
Newnham ......(above datum)	59,381	.80	8.86	1.03	1,900	400	10.16
Framilode	24,800	.85	15.00	1.31	3,600	450	11.00
Stonebench	44,650	0.36	16.92	.227	632	217	5.50
Glo'ster (say Lower Parting) ..	18,940	..	17.15	.064	783	122	9.00
Haw Bridge..................	40,000	.528	18.81	.219	784	170	6.00
Mythe Bridge	27,800	.265	20.16	.256	570	160	5.75
Upton Bridge	29,770	.301	21.23	.189	..	..	..
Pixham	34,060	.209	23.44	.342	805	125	7.50
Diglis........................	16,780	.392	24.84	.445	255	100	5.00

THE RIVER SEVERN IN FLOOD.

TABLE of the Rate of Fall as indicated by the Gauges

With the Sectional Areas and Fall per Mile in a High Flood, as observed December 4th, 1849.

Note.—These observations were taken at or before low water, when uninfluenced by the Tide.

STATIONS.	Various Freshes.			FLOOD December 4th, 1849.				
	Hght. on Gauge	Hght. on Gauge	Hght. on Gauge	Hght. on Gauge	Fall per Mile.	Area.	Greatest Wdth.	Greatest Depth
	Feet.	Feet.	Feet.	Feet.	Feet.	Sq. Ft.	Feet.	Feet.
Portishead	Freshes	not	felt	here	..	..	..	..
Beachley	..	..	..	..	..	..	..	..
Inward Point	..	..	..	..	..	..	..	..
Lidney	..	..	..	..	..	..	..	..
Sharpness...... (below datum)	2.08	2.42	2.58	1.00	..	7,596	2,400	13. 0
Newnham..... (above datum	..	..	..	13.46	1.28	4,522	730	14.75
Framilode....................	15.92	16.66	16.33	19.16	1.21	5,467	500	15.33
Stonebench	17.75	19.25	19.08	25.00	.69	2,582	275	13.25
Glo'ster (say Lower Parting) ..	19.00	20.84	21.16	29.08	1.135	2,328	170	19.50
Haw Bridge	20.75	23.16	23.75	32.84	.496	4,284	320	20.00
Mythe Bridge	22.33	24.92	25.75	35.23	.47	3,945	250	20.50
Upton Bridge	23.58	26.25	27.75	..	.23	..	..	..
Pixham	26.00	28.66	30.50	38.00		3,025	175	22.50
Diglis........................	27.42	30.08	32.16	40.16	.68	2,248	167	20.50

Remarks on the use of the Tables.

TIDES OF THE SEVERN.

TABLE OF VELOCITIES OF THE TIDAL WAVE AND BORE,

Between Sharpness and Upton, at different ranges of tide, from Captain Beechey's Admiralty Survey of the River, in the summer of 1849.

Names of Stations.	Distances apart.	Range at Sharpness.	Interval of Passage of		Rate per Minute.		
			Wave	Bore.	Wave.	Bore.	Flood Stream
Between	Feet.	Feet.	Min.	Min.	Feet.	Feet.	Feet.
Sharpness and Hock Crib	39,100	18	23	134	1,700	292	..
" "	,,	20	14½	165	2,696	237	..
" "	,,	21	10	88	3,910	444	..
" "	,,	27	6	66	6,517	592	389.9
Hock Crib and Newnham.........	19,550	18	36	44	543	444	..
" "	,,	20	29	43	674	455	..
" "	,,	21	37	43	528	455	..
" "	,,	27	24	41	815	477	..
Sharpness and Newnham	59,381	27	30	..	1,979	..	..
Newnham and Framilode.........	24,800	20	27	62	918	400	..
" "	,,	21	15	51	1,654	486	..
" "	,,	27	13	30	1,907	827	217
Framilode and Rosemary.........	21,000	21	32	54	656	389	..
" "	,,	27	21	40	1,000	525	455
Rosemary and Stonebench	23,650	21	..	29	..	816	..
" "	,,	27	27	17	876	1,373	538
Stonebench and Haw Bridge ...	58,940	21	69	59	854	999	405
Stonebench and Gloucester	,,	27	13	17	..	..	405
Haw Bridge and Mythe Bridge	27,800	27	38	..	732	..	..
Mythe Bridge and Upton.........	29,770	27	28	..	1,063	..	..
Haw Bridge and Upton............	57,570	27	..	70	..	822	..

Rate of Flood Stream, Dec. 1st, 1849,

Being Spring Tides, was about 400 feet per minute, near Stonebench, as taken by a Float drifting, but properly watched.

Sectional Area then about 2,150 square feet.

Rate of Ebb Stream, Dec. 11th, 1849,

Being Average Tides, was about 275 feet per minute, near Stonebench, as taken by a Float drifting, but properly watched.

Sectional Area then about 1,700 square feet.

TABLE OF DIMENSIONS OF DOCKS,

Depths of Water over Sills, Area of Water Space, &c. &c., of some of the principal Establishments in the United Kingdom.

NAME OF PORT AND OF DOCK.	Date of Commencement.	Dimensions of Wet Dock. Area of Water Space.	Dimensions of Wet Dock. Length	Dimensions of Wet Dock. Brdth	DEPTH Over Sill. At High Water Spring Tides		DEPTH Over Sill. At Low Water Spring Tides.		Width of Entrance.		If Entered by Lock. Length		If Entered by Lock. Brdth.	
		Acres	Yards	Yards	Ft.	In.	Ft.	Ins	Ft.	Ins.	Ft.	Ins.	Ft	Ins.
HARTLEPOOL.														
Victoria Dock	1832	20½	645	160	22	0	6	0	45	0	148	0	45	0
W. Harbour Dock	1844	7	258	126	21	6	5	6	42	0	..		..	
Ditto Extension	1850	8¾	310	132	23	6	7	6	50&60		..		..	
SUNDERLAND.														
Wearmouth Dock	1837	6	183	165	20	3	5	6	50	0	90	0	70	0
Sunderland Dock	1850	19	645	147	20	6	6	0	60	0	..		..	
LEITH.														
East Dock	1800	5¼	250	100	17	6	0	0	36	0	160	0	36	0
West Dock	..	5¼	250	100	..		..		36	0	..		..	
New Dock	1848	5	233	100	19	0	8	0	60	0	..		..	
DUNDEE.														
William IV. Dock	1815	6¾	240	126	15	6	0	0	40	0	150	0	40	0
Earl Grey Dock	..	5½	180	140	18	0	2	6	55	0	210	0	55	0
Victoria Dock (in progress)	1833	14½	430	170	21	0	5	6	60	0	230	0	60	0
MONTROSE.														
Dock	1839	3½	150	106	19	0	3	6	55	0	..		..	
ABERDEEN.														
Victoria Dock	1844	33½	950	175	21	0	10	0	60&70		250	0	60	0
DUBLIN.														
Royal Canal Dock	1789	1½	252	32	15	0	4	6	27	0	118	0	27	0
Old Custom House Dock	1770	2	139	72	18	0	..		36	0	..		..	
George's Dock	1770	1¾	107	86	18	0	..		36	0	..		..	
Large Dock	1816	4½	217	100	18	0	..		36	0	180	0	36	0
Grand Canal Dock	1793	24½	1005	120	18	0	7	6	35	6	150	0	35	6
GALWAY.														
New Dock	1833	7½	239	193	16	0	1	0	56	0	..		..	
LIMERICK.														
Dock (in progress)	..	7¾	270	130	22	0	..		50	0	..		..	
CORK (proposed).														
North Dock	..	6	..	..	18	6	6	0	45	0	180	0	45	0
South Dock	..	12	..	..										
BRISTOL.														
Cumberland Basin	1804	4½	245	90	30	0	0	7	54&45		260		54&67	
Bathurst Basin	..	2	140	70	..		0	9	35	8	152	0	..	
Floating Harbour	..	63½	1800	85	30 to 34		..		45 &35		186 & 150		45 & 35	
PLYMOUTH.														
Great Western Dock	1847	13	420	150	24	0	6	0	80	0	250	0	55	0
NEWPORT.														
Dock	1835	4	270	73	25	0	25	0	61	0	225	0	61	0
CARDIFF.														
Bute Docks	1838	21	1333	66	19	0	19	0	36	0	152	0	36	0
SWANSEA (in progress).	1849	12½	760	80	21	6	8	6	56 &70		165	0	56	0
IPSWICH.														
Dock	1837	33	1120	140	16	6	3	0	45	0	150	0	45	0
GREAT GRIMSBY.														
Dock (in progress)	1846	20	600	167	26	0	4	0	70	0	300	0	70	0
HULL														
Old Dock	1774	10	567	84	18	0	2	9	38	0	121	0	38	0
Humber Dock	1803	7	300	110	24	0	5	0	42	0	158	6	42	0
Junction Dock	1826	6	214	140	..		..		36	6	130	0	36	6
Railway Dock	1845	2¾	240	55	..		..		43	0	..		..	
Victoria Dock	1846	12½	480	126	25	0	6	6	50	0	120	6	32	0
Ditto Half-Tide Basin	..	3	110	115	25	0	6	6	60 &32		120	6	60 &32	
GOOLE.														
Barge Dock	1820	3	290	50	9	0	9	0	22	0	72	6	19	6
Ship Dock	1820	3½	234	67	17	0	17	0	29	6	119	0	29	6
Harbour Dock	1820	1½	87	67	17	0	17	0	33	6	72&119		22 &33	
Steam Ship Dock	1836	4	120	164	19	0	19	0	58	0	210	0	58	0
Railway Dock	1847	2¾	200	67	19	0	19	0	58	0	210	0	58	0
STOCKTON.														
Middlesborough Dock	1839	10	400	130	19	0	5	0	30	0	132	0	30	0

TABLE OF DOCKS AT LIVERPOOL,

With the principal Dimensions, Depth of Water over Sills, &c.

	H.W. above Old Dock Sill.		L.W. below Old Dock Sill.
Average Spring Tides	18.8	..	8.9
„ Neap Tides	11.8	..	1.9
Equinoctial Spring Tides	20.0	..	11.0
Extraordinary Spring Tide, as marked on Leasowe Lighthouse	25.0		

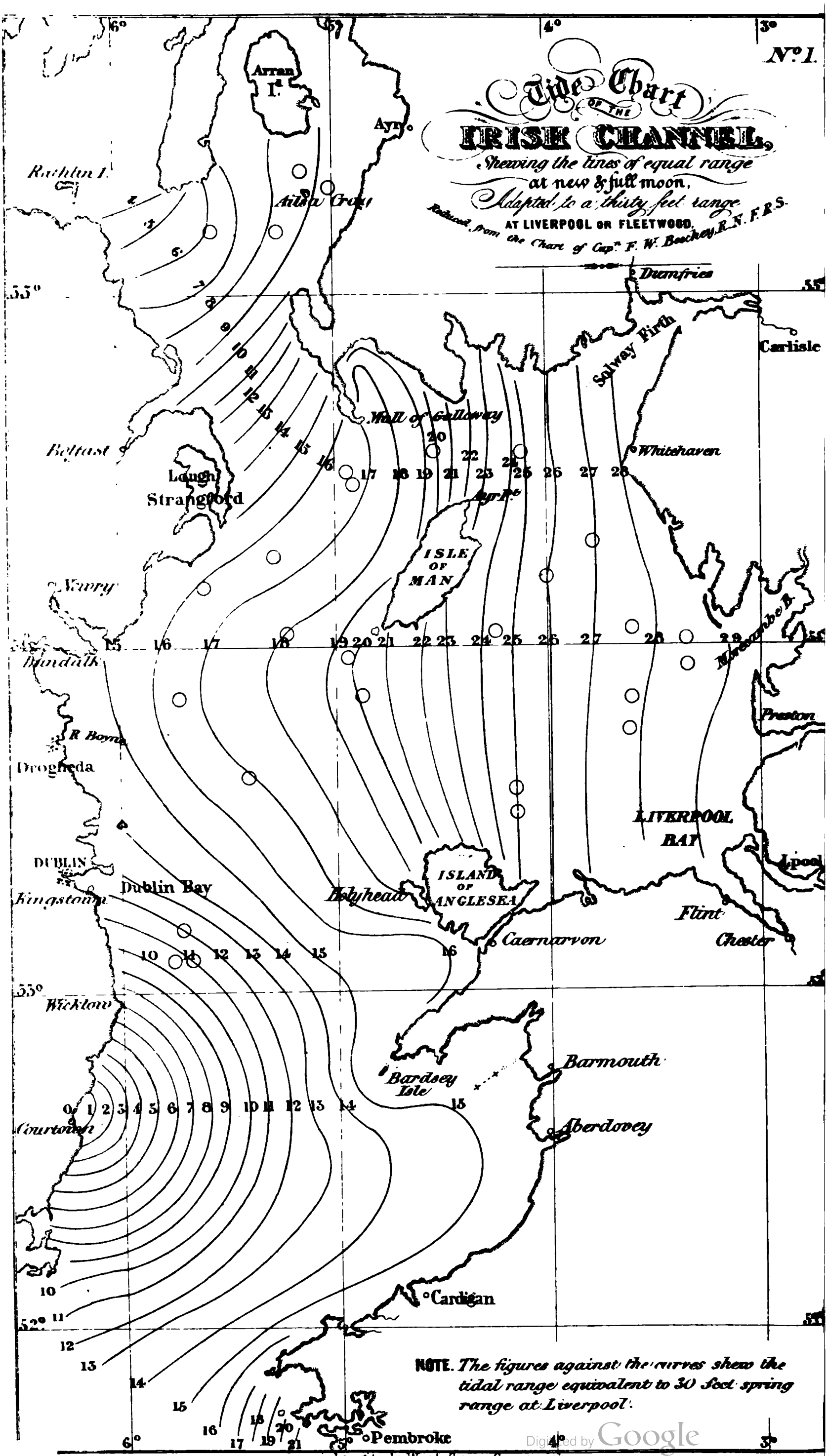
Total Area of Docks ....acres 177.80 .. Quay Space.... 14.7 miles.
„ Dry Basins „ 20. 2 .. River Wall.... 5.0 „

NAME OF DOCK.	Dimensions of Wet Dock. Area of Water Space.	Lngth	Brdth	DEPTH over Sill. At High Water Spring Tides.		At Low Water Spring Tides.		Width of Entrance.	
	Acres	Yards	Yards	Ft.	In.	Ft.	Ins.	Ft.	Ins.
TIDAL BASINS.									
Sandon Basin	6. 19	167	150						
Prince's Basin	4. 32	160	140	..		..		170. 0	
Seacombe Basin	0. 37	70	25						
George's Basin	3. 38	182	90	..		..		170. 0	
George's Ferry Basin	0. 28	66	23						
Queen's Basin	5. 04	220	100			Dry, or above L. W.			
South Ferry Basin	0. 60	70	30						
WET DOCKS.									
Sandon Dock	10. 02	320	145	24	9	2	3	70	0
Wellington Half-tide Dock	3. 17	120	100	25	0	2	0	70 &50	
Wellington Dock	7. 85	300	120	24	3	2	9	70	0
Bramley Moore Dock	9. 64	350	120	24	3	2	9	60 &60	
Nelson Dock	7. 99	266	120	24	9	2	3	60	0
Stanley Dock	7. 03	183	146	23	11	3	1	51	0
Collingwood Dock	5. 05	166	120	25	0	2	0	60	0
Salisbury Dock	3. 44	170	90	25	2	1	10	60 &50	
Clarence Dock	5. 77	235	100	21	5	5	7	47	0
Clarence Half-tide Dock	3. 93	210	100	23	9	3	3	50 &45	
Trafalgar Dock	5. 88	272	120	23	9	3	3	45 &45	
Victoria Dock	5. 63	265	100	23	2	3	10		
Waterloo Dock	5. 58	260	115	24	8	2	4	40 &45	
Prince's Dock	11. 13	495	115	24	2	2	10	45 &45	
George's Dock	5. 03	225	110	22	9	4	3	42 &40	
Canning Dock	4. 08	210	98	24	6	2	6	45	0
Canning Half-tide Dock	2. 55	200	70	24	7	2	5	45 &45	
Albert Dock	7. 61	235	150	24	7	2	5	45 &45	
Salthouse Dock	4. 65	275	130	24	3	2	9	45	0
King's Dock	7. 59	261	145	23	3	3	9	42	0
Queen's Dock	10. 38	448	110	21	5	5	7	42 &42	
Union Dock	2. 59	126	86	20	0	7	0	42	0
Coburg Dock	4. 27	180	110	23	3	3	9	70	1
Brunswick Dock	12. 44	415	142	22	9	4	3	42	0
Brunswick Half-tide Dock	1. 43	100	60	24	3	2	9	45 &42	
Toxteth Dock	1. 07	..	..	23	3	3	9	40	0
GRAVING DOCKS.									
Sandon, No. 1 East		180. 0		21	9	5	3	60	0
„ No. 2		180. 0		21	9	5	3	70	0
„ No. 3		180. 0		21	9	5	3	60	0
„ No. 4		180. 0		21	9	5	3	70	0
„ No. 5		180. 0		21	9	5	3	45	0
„ No. 6		180. 0		21	9	5	3	45	0
Huskisson		103. 0		24	9	2	3	80	0
Clarence, No. 1, Old		135. 0		21	3	5	9	45	0
„ No. 1, New		97. 0		18	9	8	3	45	0
„ No. 2, Old		138. 0		21	3	5	9	45	0
„ No. 2, New		96. 0		18	9	8	3	32	10
Canning, No. 1		147. 0		16	7	10	5	35	9
„ No. 2		160. 0		18	10	8	2	35	9½
Queen's, No. 1		146. 0		19	11	7	1	42	0
„ No. 2		145. 0		19	11	7	1	42 &70 at H.W	
Brunswick, No. 1		133. 0		20	9	6	3	42	0
„ No. 2		133. 0		20	9	6	3	42	0

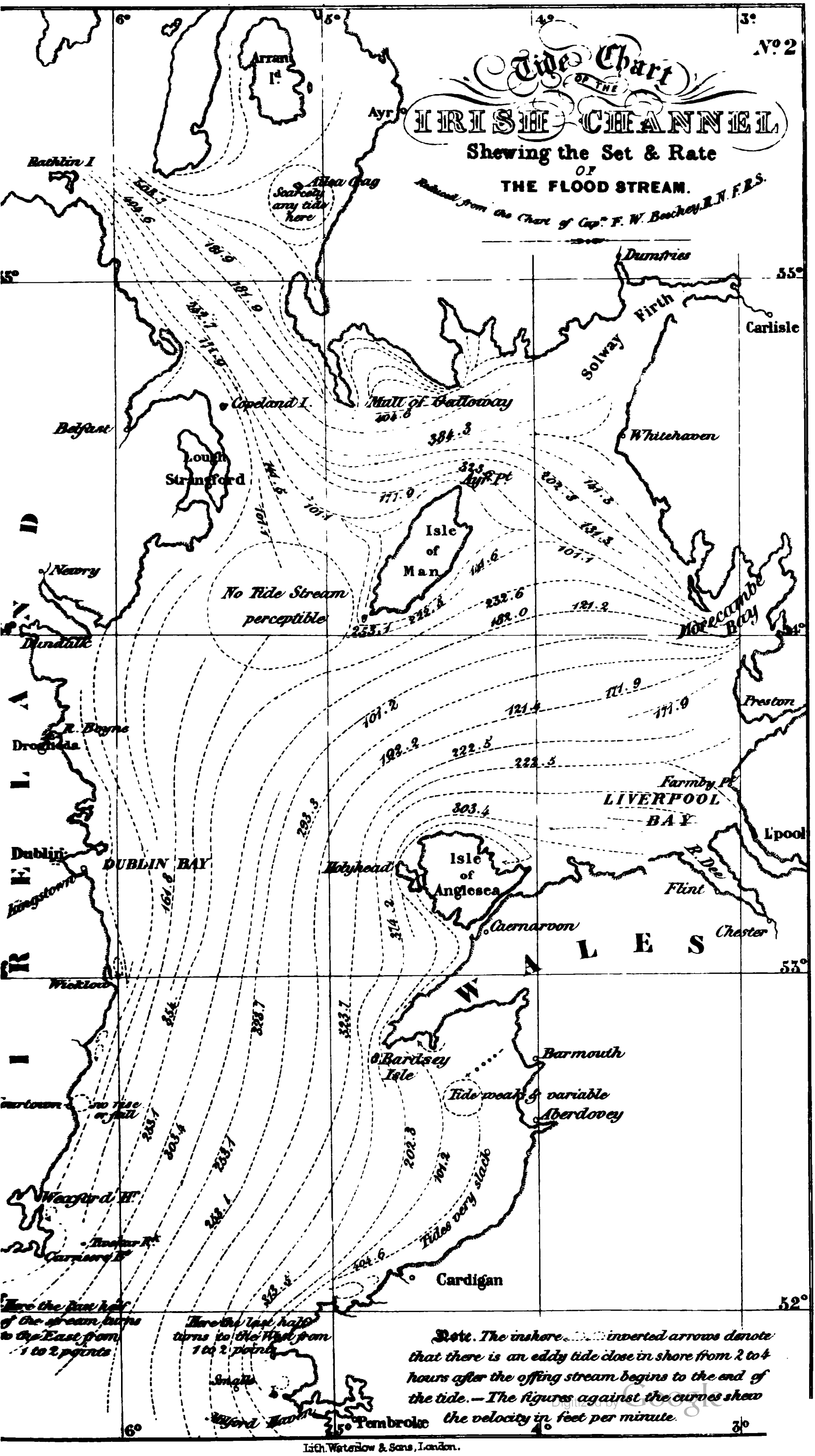
	Area. Acres.	Depth over Sill. H.W.S.T. Ft. Ins.	L.W.S.T. Ft. Ins.	Width of Entrance. Feet.
BIRKENHEAD DOCKS—Great Low Water Basin	33	39 0	12 0	
„ Morpeth Dock } Egerton Dock }	7	23 3	..	50
„ Great Float	150	37 0	10 0	60 & 85

LIST OF PLATES.

	PLATE NO.
Tide Chart of the Irish Channel, shewing lines of equal range at new and full moon	1
Tide Chart of the Irish Channel, shewing the set and rate of the flood stream	2
Sketch of the course of the 7 o'clock stream of tide in the English Channel, at new and full moon	3
Do. do. do. Irish Channel	4
Map of the World, shewing cotidal lines	5
River Mersey—Diagram from simultaneous observations, shewing surface of water when high and low water at various points ...	6
River Severn—Diagram shewing line of high and low water, and flood levels	7
River Tyne—Diagram of surface of river when high and low water at either end, during a spring tide	7
River Nene—Diagram shewing surface of river when high and low water at Wisbech, during a spring tide	8



Longitude West from Greenwich.



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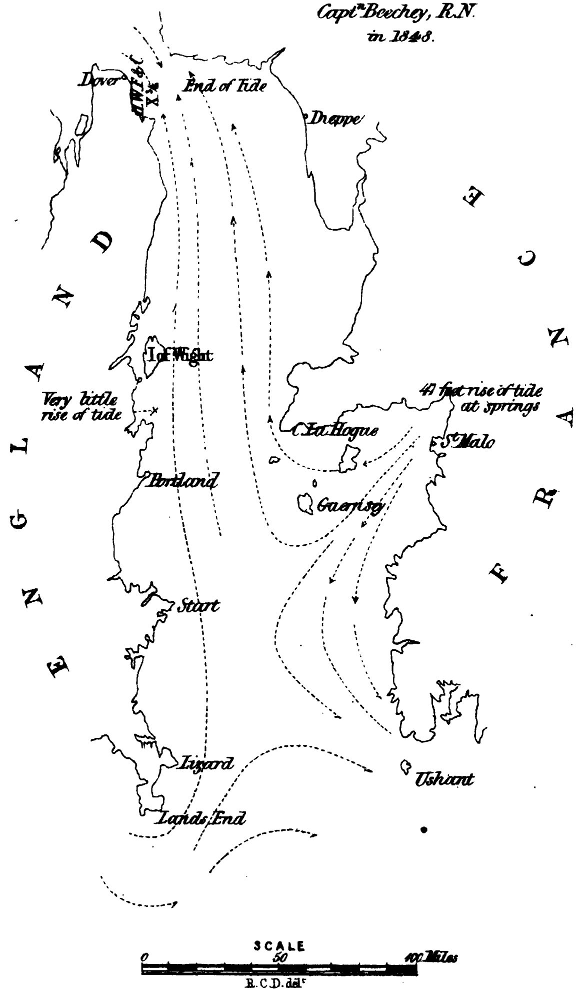
HYD. TABLES
Plate No. 3

SKETCH
of the
Course of the 7 o' clock stream of Tide
in the
ENGLISH CHANNEL
Reduced from a Plan made by
Captn. Beechey, R.N.
in 1848.



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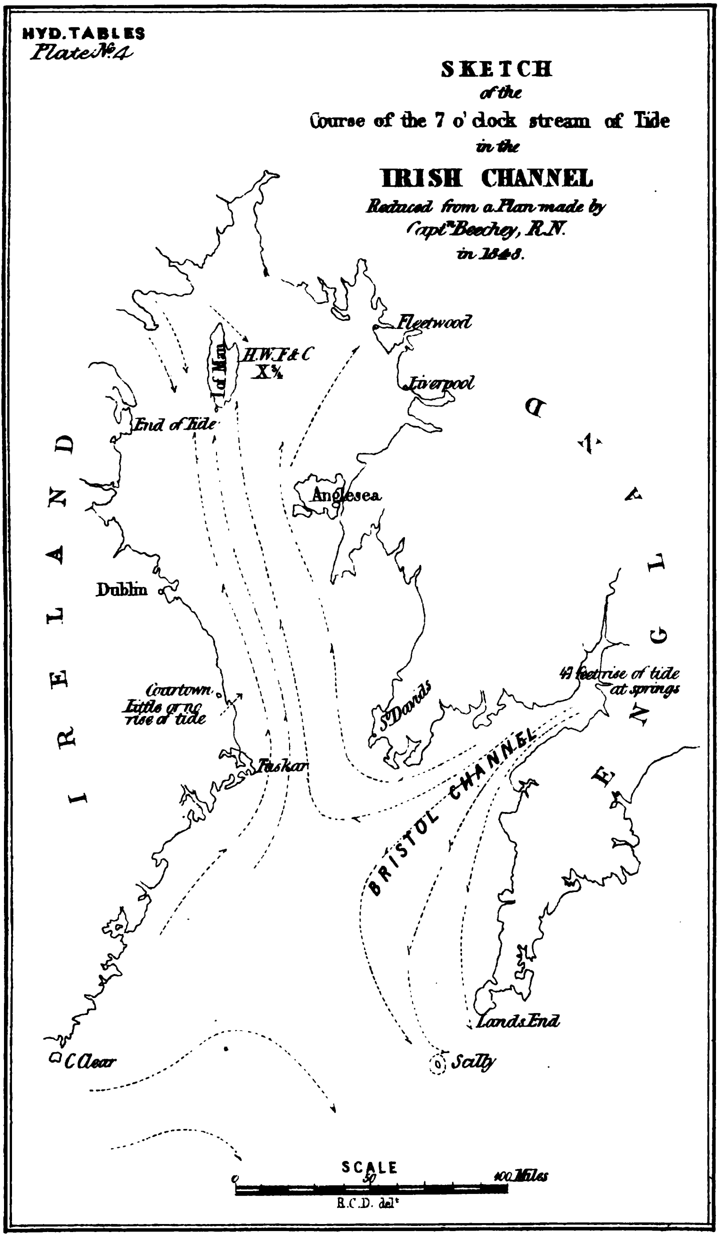

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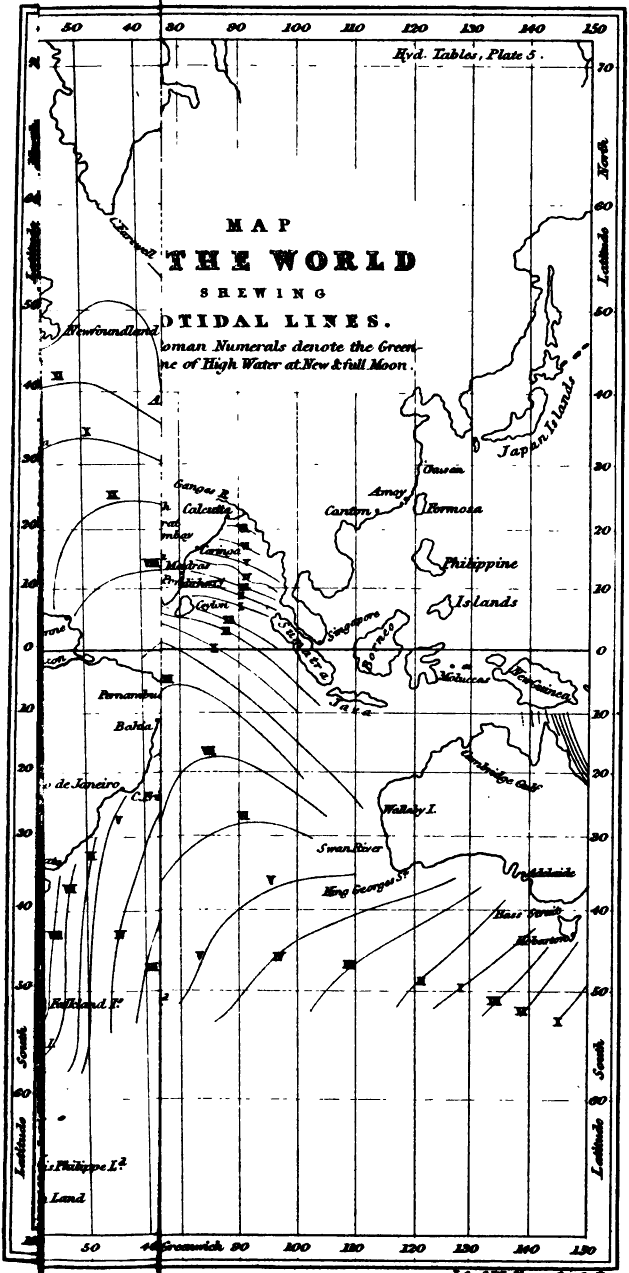

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Hyd: Tables Plate 6.

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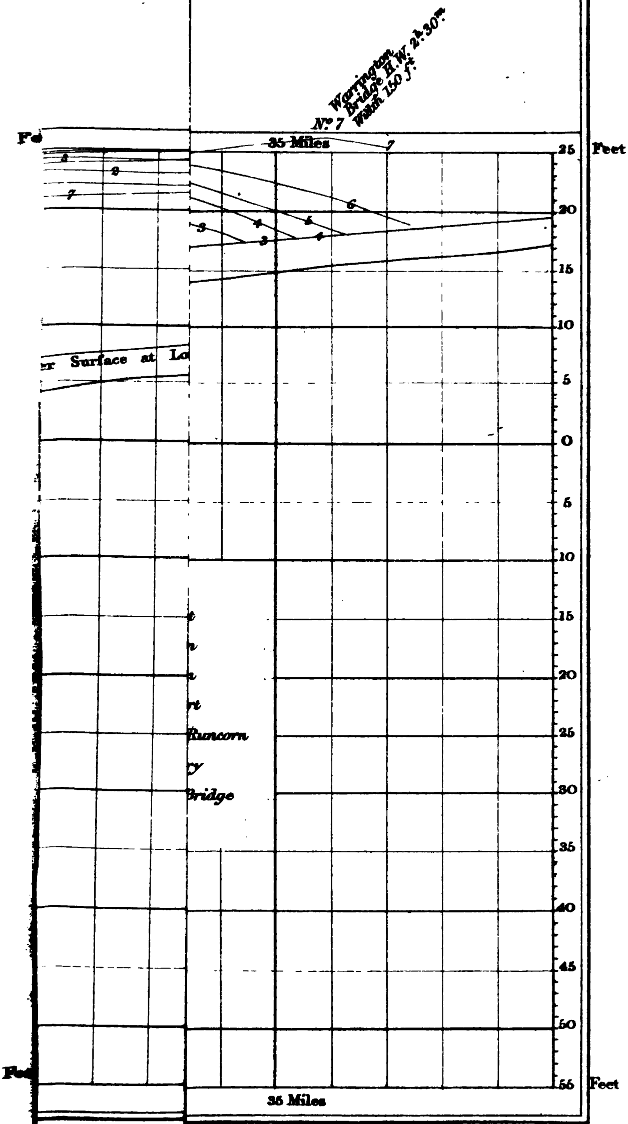

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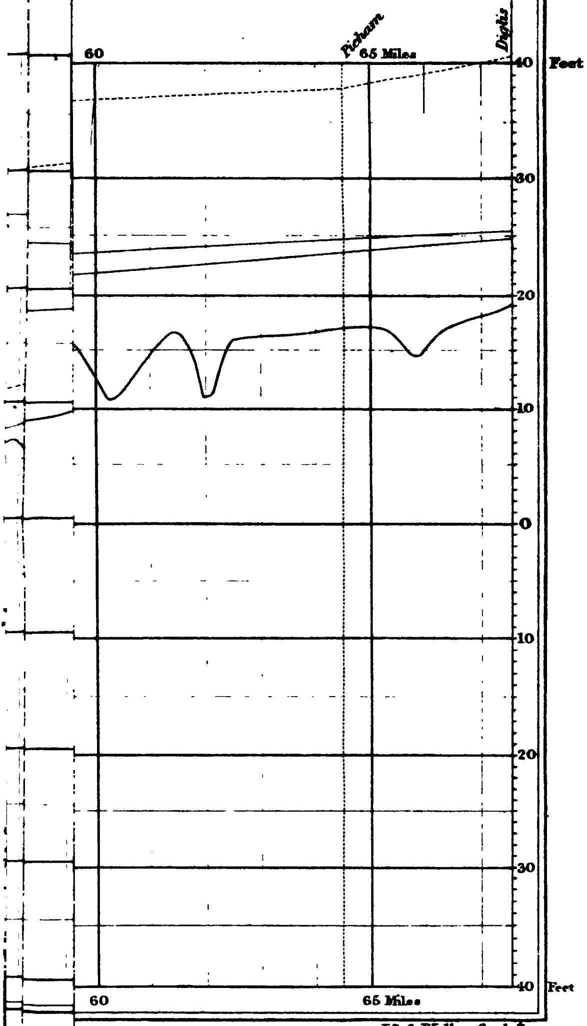


J. & C. Walker Sculp.t

APPENDIX
TO
REMARKS ON THE USE OF THE TABLES.

FLOODS OF LARGE DISTRICTS.

Extract from Mr. Thomas John Taylor's work on the Improvement of the Tyne, page 26. Lambert, Newcastle, 1851.

"It is not unusual for the river Tyne, during a land flood, to discharge 36 millions of tons of water in 24 hours, being equivalent to a net quantity of half an inch of rain over the entire extent of its basin. The highest sources are about 1,200 feet above the sea level; but the mean elevation of the basin may be taken at 500 feet. Now 36 million tons in 24 hours are 25,000 tons per minute; and a horse-power being 33,000lbs. equal to 14·7 tons, we have $\frac{25,000 \times 500}{14 \cdot 7} = 850,340$ horses' power.

"A flood which rose, at its highest elevation, a few inches above the floor of the house at Ryton island, discharged, according to my calculation, upwards of 70 millions of tons of water in 24 hours (70,383,909), to which may be added the waters at the same time extending over the Haughs, estimated at 9,874,286: in all 80,258,195 tons, or say 80 millions of tons in 24 hours.

"By way of contrast, I may mention the quantity of water passing the same point on July 19, 1850, when the river was free from tide or fresh, and extremely low; the rate of discharge was only 16,025 cubic feet per minute, equal to 659,890 tons in 24 hours.

"Thus the Tyne varies in its volume of land water in the proportion of 1 to 120.

"The ordinary state of the Nile is to its flood state as 1 to 5.

"The ordinary state of the Ganges is to its flood state as 1 to 5."

STRENGTH OF CYLINDRICAL STEAM BOILERS.

TABLE OF THICKNESS OF METAL

For boilers of equal strength, at a pressure of 450 lbs. per square inch, taking bursting pressure at the ultimate strength of the riveted joints, or 34,000 lbs. per square inch.

Diameters of Boilers.	Thickness of Plates.	Diameters of Boilers.	Thickness of Plates.
Ft. Ins.	Inch.	Ft. Ins.	Inch.
3 0	.25	6 0	.50
3 6	.29	6 6	.54
4 0	.33	7 0	.58
4 6	.37	7 6	.62
5 0	.42	8 0	.66
5 6	.46		

This Table is from a recent paper by Mr. Fairbairn, of Manchester, who considers that if the strength of boiler plate be taken at 1.00
That of a double riveted joint is........................ .75
" single riveted joint is .... .56

EXPERIMENTS ON THE HYDRAULIC RAM.

By Messrs. HUNTER and ENGLISH.

Fall in feet.	Quantity of Water expended in gallons.	Water raised in gallons.	Height of Stand Pipe. Feet.	Time in minutes.
9·32	515	68	40·93	14
9·41	493	68	40·84	20
9·33	530	68	40·92	14
9·31	504	68	40·94	21
9·32	514	68	40·93	22

NOTE.—The height from the outlet of the ram to the top of the stand pipe is 50·25 feet. Therefore the fall in feet deducted from the above will give the height to which the water was raised above the head. The difference in time of filling the cistern is owing to variations in the adjustment of the beat of the valve,—slow motion giving the best duty.

TIDES OF THE ENGLISH CHANNEL AND NORTH SEA.

Captain Beechey's paper, in the *Philosophical Transactions*, Part II., for 1851, contains his investigations into the currents and tides of these seas similar to those on the tides of the Irish Sea. Instead of these channels having a stream turning progressively later as the tide advances up the strait, it was found that the tide turns off the Start on one side of Dover, and the Lynn deeps on the other side; between these points the tide sets steadily *towards* Dover, while the water is *rising* there; and *away* from Dover in each direction when the tide is *falling* there. This "true channel stream" is about 180 miles in length each way, from the point of union, towards Lynn in one direction, and towards the Start in the other. The point of union of the tides off the straits of Dover oscillates between Beachy Head and the North Foreland, a distance of sixty miles. When the water at Dover begins to fall the separation takes place off Beachy Head, gradually creeping to the eastward as the fall of tide at Dover continues—at two hours after high water it gets to Hastings, at three hours it arrives at Rye; and when it is low water at Dover the line of separation is between Dunkirk and the North Foreland.

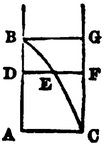
It appears, from the elaborate charts which accompany Captain Beechey's paper, "that for a period of six hours after high water at Dover and for five hours before that time, the great stream of the English Channel and North Sea maintain a steady direction from and towards Dover." Between Cromer and the North Foreland, Captain Beechey states, that there is not half an hour's retardation in the time of slack water from the time of high water at Dover, while in the establishment there is a difference of five hours; on the other side the stream, between Start point and Alderney, turns with high water at Dover, although the difference of establishment is also five hours. The whole paper is worth close study, being accompanied by very elaborate maps and diagrams. Reasoning on these facts, we find that when it is high water at Dover (which is five hours after high water at Start point) the tide has fallen about thirteen feet off the Start—or there is about fifteen feet actual difference of level in the water surface at the two places, when the current turns at spring tides; taking this difference, we have a fall of one inch per mile of the surface; this is ample for the gravitating power to produce the tidal stream, which appears to vary from 120 to 400 feet per minute.

HYDRAULIC PROBLEMS,

WHICH ARE OCCASIONALLY USEFUL TO THE ENGINEER, INVOLVING THE USE OF FLUXIONAL CALCULUS.

(From Dr. Hutton's Mathematical Tracts.)

PROBLEM—To determine the Time of emptying any Ditch, or Inundation, &c., by a Cut or Notch, from the Top to the Bottom of it.



Let $x =$ AB, the variable height of the descending water at any time;
$b =$ AC, the breadth of the cut;
$d =$ the whole or first depth of water;
A $=$ the area of the surface of the water in the ditch;
$g = 16\frac{1}{12}$ feet, the descent by gravity in $1''$.

Now, the velocity at any point D, is as $\sqrt{\text{BD}}$, that is as the ordinate DE of a parabola BEC, whose base is AC, and altitude AB. Therefore the velocities at all the points in AB are as all the ordinates in the parabola. Consequently, the quantity of water running through the cut ABGC, in any time, is to the quantity which would run through an equal aperture placed all at the bottom, in the same time, as the area of the parabola ABC, to the area of the parallelogram ABGC, that is, as 2 to 3.

But $\sqrt{g} : \sqrt{x} :: 2g : 2\sqrt{gx}$, the velocity at AC; therefore $2\sqrt{gx} \times bx \times \frac{2}{3} = \frac{4}{3}\, bx\sqrt{gx}$ is the quantity discharged per second through ABGC; and consequently $\frac{4bx\sqrt{gx}}{3\text{A}}$ is the velocity per second of the descending surface. Hence then $\frac{4bx\sqrt{gx}}{3\text{A}} : -\dot{x} :: 1'' : \frac{-3\text{A}\dot{x}}{4bx\sqrt{gx}} = \dot{t}$, the fluxion of the time of descending.

Now when A the surface of the water is constant, or the ditch is equally broad throughout, the correct fluent of this fluxion gives $t = \frac{3\text{A}}{2b\sqrt{g}} \times \frac{\sqrt{d} - \sqrt{x}}{\sqrt{dx}}$ for the general time of sinking the surface to any depth x. And when $x = 0$, this expression is infinite; which shows that the time of a complete exhaustion is infinite.

But if $d = 9$ feet, $b = 2$ feet, $A = 21 \times 1000 = 21000$, and it be required to exhaust the water down to $\frac{1}{16}$ of a foot, deep; then $x = \frac{1}{16}$, and the above expression becomes $\frac{3 \times 21000}{4 \times 4\frac{1}{96}} \times \frac{3 - \frac{1}{4}}{\frac{3}{4}} = 14400''$, or just 4 hours for that time. And if it be required to depress it 8 feet, or till 1 foot depth of water remain in the ditch, the time of sinking the water to that point will be 43′ 38″.

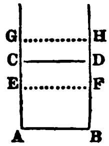
Again, if the ditch be the same depth and length as before, but 20 feet broad at bottom, and 22 at top; then the descending surface will be a variable quantity, and it will be $\frac{90 + x}{90} \times 20{,}000$; hence, in this case the fluxion of the time, or $\frac{-3A\dot{x}}{4bx\sqrt{gx}}$, becomes $\frac{-500}{3b\sqrt{g}} \times \frac{90+x}{x\sqrt{x}}\,\dot{x}$; the correct fluent of which is $t = \frac{1000}{3b\sqrt{g}} \times \left(\frac{90-x}{\sqrt{x}} - \frac{90-d}{\sqrt{d}}\right)$ for the time of sinking the water to any depth x.

Now when $x = 0$, this expression for the complete exhaustion becomes infinite.

But if ... $x = 1$ foot, the time t is 42′ 56″$\frac{1}{2}$.
And when $x = \frac{1}{16}$ foot, the time is 3[h] 50′ 28″$\frac{1}{2}$.

PROBLEM.—To determine the Time of filling the Ditches of a Fortification 6 feet deep with Water, through the sluice of a trunk of 3 feet square, the bottom of which is level with the bottom of the Ditch; the height of the supplying water being 9 feet above the bottom of the Ditch.

Let ACDB represent the area of the vertical sluice, being a square of 9 square feet, and AB level with the bottom of the ditch. And suppose the ditch filled to any height AE, the surface being then at EF,



Put $a = 9$ the height of the head or supply;
$b = 3 = AB = AC$;
$g = 16\frac{1}{12}$;
$A =$ the area of a horizontal section of the ditches;
$x = a - AE$, the height of the head above EF.

Then $\sqrt{g} : \sqrt{x} :: 2g : 2\sqrt{gx}$ the velocity with which the water presses through the part AEFB; and therefore $2\sqrt{gx} \times AEFB = 2b\sqrt{gx}\,(a-x)$ is the quantity per second running through AEFB. Also, the quantity running per second through ECDF is $2\sqrt{gx} \times \frac{11}{12}ECDF = \frac{11}{6}b\sqrt{gx}$

$(b-a+x)$ nearly. For the real quantity is, by proceeding as in the last problem, the difference between two parab. segs. the alt. of the one being x, its base b, and the alt. of the other $a-b$; and the medium of that dif. between its greatest state at AB, where it is $\frac{8}{10}$AD, and its least state at CD, where it is 0, is nearly $\frac{11}{12}$ ED. Consequently, the sum of the two, or $\frac{1}{6}b\sqrt{gx}\,(a+11b-x)$ is the quantity per second running in by the whole sluice ACDB. Hence, then, $\frac{1}{6}b\sqrt{gx} \times \frac{a+11b-x}{A} = v$, the rate or velocity per second with which the water rises in the ditches;

and so $v : -\dot{x} :: 1'' : \dot{t} = -\frac{\dot{x}}{v} = \frac{-6A}{b\sqrt{g}} \times \frac{x^{-\frac{1}{2}}\dot{x}}{c-x}$ the fluxion of the time of filling to any height AE, putting $c = a + 11\,b$.

Now when the ditches are of equal width throughout, A is a constant quantity, and in that case a correct fluent of this fluxion is $t = \frac{6A}{b\sqrt{gc}} \times \log. \left(\frac{\sqrt{c}+\sqrt{a}}{\sqrt{c}-\sqrt{a}} \times \frac{\sqrt{c}-\sqrt{x}}{\sqrt{c}+\sqrt{x}}\right)$ the general expression for the time of filling to any height AE, or $a - x$, not exceeding the height AC of the sluice. And when $x = AC = a - b = d$ suppose, then $t = \frac{6A}{b\sqrt{gc}} \times \log. \left(\frac{\sqrt{c}+\sqrt{a}}{\sqrt{c}-\sqrt{a}} \cdot \frac{\sqrt{c}-\sqrt{d}}{\sqrt{c}+\sqrt{d}}\right)$ is the time of filling to CD the top of the sluice.

Again, for filling to any height GH above the sluice, x denoting as before $a -$ AG the height of the head above GH, $2\sqrt{gx}$ will be the velocity of the water through the whole sluice AD: and therefore $2b^2\sqrt{gx}$ the quantity per second, and $\frac{2b^2\sqrt{gx}}{A} = v$, the rise per second of the water in the ditches; consequently $v : -\dot{x} :: 1'' : \dot{t} = -\frac{\dot{x}}{v} = \frac{-A}{2b^2\sqrt{g}} \times \frac{\dot{x}}{\sqrt{x}}$ the general fluxion of the time; the correct fluent of which, being 0, when $x = a-b = d$, is $t = \frac{A}{b^2\sqrt{g}}(\sqrt{d} - \sqrt{x})$ the time of filling from CD to GH.

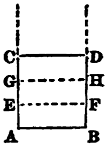
Then the sum of the two times, namely, that of filling from AB to CD, and that of filling from CD to GH, is $\frac{A}{b\sqrt{g}}\left[\frac{\sqrt{d}-\sqrt{x}}{b} + \frac{6}{\sqrt{x}} \log. \left(\frac{\sqrt{c}+\sqrt{a}}{\sqrt{c}-\sqrt{a}} \cdot \frac{\sqrt{c}-\sqrt{d}}{\sqrt{c}+\sqrt{d}}\right)\right]$ for the whole time required. And, using the numbers in the prob., this becomes $\frac{A}{3\sqrt{g}}\left[\frac{\sqrt{6}-\sqrt{3}}{3} + \frac{6}{\sqrt{42}} \times 1. \left(\frac{\sqrt{42}+\sqrt{9}}{\sqrt{42}-\sqrt{9}} \cdot \frac{\sqrt{42}-\sqrt{6}}{\sqrt{42}+\sqrt{6}}\right)\right] = 0.03577277$A, the time in terms of A.

the area of the length and breadth, or horizontal section of the ditches. And if we suppose that area to be 200,000 square feet, the time required will be 7154″, or $1^h\ 59'\ 14''$.

And if the sides of the ditch slope a little, so as to be a little narrower at the bottom than at top, the process will be nearly the same, substituting for A its variable value, as in the preceding problem. And the time of filling will be very nearly the same as that above determined.

PROBLEM.—If the Water for filling the Ditches be the Tide, which at low water is below the bottom of the trunk, and rises to suppose 9 feet above the bottom of it by a regular rise of one foot in half-an-hour; it is required to ascertain the time of filling it to 6 feet high, as in the last problem.

Let ACDB represent the sluice; and when the tide has risen to any height GH, below CD the top of the sluice, without the ditches, let EF be the mean height of the water within.



And put $b = 3 = $ AB $=$ AC;

$g = 16\frac{1}{12}$;

A $=$ horizontal section of the ditches;

$x = $ AG;

$z = $ AE.

Then $\sqrt{g} : \sqrt{\text{EG}} :: 2g : 2\sqrt{g\ (x-z)}$ the velocity of the water through AEFB; and $\sqrt{g} : \sqrt{\text{EG}} :: \frac{4}{3}g : \frac{4}{3}\sqrt{g\ (x-z)}$ the mean velocity through EGHF; therefore $2bz\sqrt{g\ (x-z)}$ is the quantity per sec. through AEFB; and $\frac{4}{3}b\ (x-z)\ \sqrt{g\ (x-z)}$ is the same through EGHF; consequently $\frac{2}{3}b\sqrt{g} \times (2x+z)\ \sqrt{(x-z)}$ is the whole through AGHE per second. This quantity divided by the surface A, gives $\frac{2b\sqrt{g}}{3\text{A}} \times (2x+z)\ \sqrt{(x-z)} = v$ the velocity per second with which EF, or the surface of the water in the ditches, rises. Therefore

$$v : \dot{z} :: 1'' : \dot{t} = \frac{\dot{z}}{v} = \frac{3\text{A}}{2b\sqrt{g}} \times \frac{\dot{z}}{(2x+z)\sqrt{(x-z)}}.$$

But as GH rises uniformly 1 foot in 30′ or 1800″, therefore 1 : AG :: 1800″ : $1800x = t$ the time of the tide rising through AG; consequently

$$\dot{t} = 1800\dot{x} = \frac{3\text{A}}{2b\sqrt{g}} \times \frac{\dot{z}}{(2x+z)\sqrt{(x-z)}},\ \text{or}\ m\dot{z} = (2x+z)\sqrt{(x-z)}\,.\,\dot{x}$$

is the fluxional equa. expressing the relation between x and z; where m $= \frac{A}{1200b\sqrt{g}} = \frac{3200}{231}$ or $13\frac{197}{231}$ when $A = 200{,}000$ square feet.

Now to find the fluent of this equation, assume $z = Ax^{\frac{5}{2}} + Bx^{\frac{8}{2}} + Cx^{\frac{11}{2}} + Dx^{\frac{14}{2}}$ &c. So shall

$$\sqrt{(x-z)} = x^{\frac{1}{2}} - \frac{A}{2}x^{\frac{4}{2}} - \frac{A^2 + 4B}{8}x^{\frac{7}{2}} - \frac{A^3 + 4AB + 8C}{16}x^{\frac{10}{2}} \text{ \&c.,}$$

$$2x + z = 2x + Ax^{\frac{5}{2}} + Bx^{\frac{8}{2}} + Cx^{\frac{11}{2}} \text{ \&c.}$$

$$(2x + z)\sqrt{(x-z)}\,\dot{x} = 2x^{\frac{3}{2}}\dot{x} * - \frac{3A^2}{4}x^{\frac{9}{2}}\dot{x} - \frac{A^3 + 6AB}{4}x^{\frac{12}{2}}\dot{x} \text{ \&c.,}$$

$$\text{and } m\dot{z} = \tfrac{5}{2}mAx^{\frac{3}{2}}\dot{x} + \tfrac{8}{2}mBx^{\frac{6}{2}}\dot{x} + \tfrac{11}{2}mCx^{\frac{9}{2}}\dot{x} + \tfrac{14}{2}mDx^{\frac{12}{2}}\dot{x} \text{ \&c.}$$

Then equating the coefficients of the like terms,

so shall	and consequently,
$\frac{5}{2}mA = 2,$	$A = \frac{4}{5m},$
$\frac{8}{2}mB = 0,$	$B = 0,$
$\frac{11}{2}mC = -\frac{3}{4}A^2,$	$C = -\frac{24}{275m^3},$
$\frac{14}{2}mD = -\frac{3}{4}A^3 - \frac{3}{2}AB,$	$D = -\frac{16}{875m^4}$
&c.;	&c.

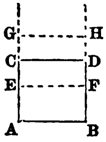
Which values of A, B, C, &c., substituted in the assumed value of z, give

$$z = \frac{4}{5m}x^{\frac{5}{2}} * - \frac{24}{275m^3}x^{\frac{11}{2}} - \frac{16}{875m^4}x^{\frac{14}{2}} \text{ \&c.}$$

$$\text{or } z = \frac{4}{5m}x^{\frac{5}{2}} \text{ very nearly.}$$

And when $x = 3 =$ AC, then $z = .886$ of a foot, or $10\frac{2}{3}$ inches, $=$ AE, the height of the water in the ditches when the tide is at CD or 3 feet high without, or in the first hour and half of time.

Again, to find the time, after the above, when EF arrives at CD, or when the water in the ditches arrives as high as the top of the sluice,



The notation remaining as before,
then $2bz\sqrt{g}\,(x - z)$ per sec. runs through AF,
and $\frac{4}{3}b(3 - z)\sqrt{g(x - z)}$ per sec. through ED nearly;
therefore $\frac{2}{3}b\sqrt{g} \times (12 + z)\sqrt{(x - z)}$ is the whole per sec. through AD nearly.

conseq. $\frac{2b\sqrt{g}}{5A} \times (12 + z)\sqrt{(x - z)} = v$ is the velocity per second of the point E; and therefore

$$v : \dot{z} :: 1'' : \dot{t} = \frac{\dot{z}}{v} = \frac{5\text{A}}{2b\sqrt{g}} \times \frac{\dot{z}}{(12+z)\sqrt{(x-z)}} = 1800\dot{x} \text{ or}$$

$$m\dot{z} = (12+z)\sqrt{(x-z)}\,\dot{x}, \text{ where } m = \frac{\text{A}}{720b\sqrt{g}} = 23\tfrac{2}{25} \text{ nearly.}$$

Assume $z = \text{A}x^{\frac{3}{2}} + \text{B}x^{\frac{4}{2}} + \text{C}x^{\frac{5}{2}} + \text{D}x^{\frac{6}{2}}$ &c. So shall

$$\sqrt{(x-z)} = x^{\frac{1}{2}} - \frac{\text{A}}{2}x^{\frac{2}{2}} - \frac{\text{A}^2+4\text{B}}{8}x^{\frac{3}{2}} - \frac{\text{A}^3+4\text{AB}+8\text{C}}{16}x^{\frac{4}{2}} \text{ &c.}$$

$$12 + z = 12 + \text{A}x^{\frac{3}{2}} + \text{B}x^{\frac{4}{2}} + \text{C}x^{\frac{5}{2}} \text{ &c.};$$

$$(12+z).\sqrt{(x-z)}\,.\,\dot{x} = 12x^{\frac{1}{2}}\dot{x} - 6\text{A}x^{\frac{2}{2}}\dot{x} - (\tfrac{3}{2}\text{A}^2 + 6\text{B})x^{\frac{3}{2}}\dot{x} \text{ &c.}$$

$$m\dot{z} = \tfrac{3}{2}m\text{A}x^{\frac{1}{2}}\dot{x} + \tfrac{4}{2}m\text{B}x^{\frac{2}{2}}\dot{x} + \tfrac{5}{2}m\text{C}x^{\frac{3}{2}}\dot{x} \text{ &c.}$$

Then, equating the like terms, &c., we have

$$\text{A} = \frac{8}{m},\ \text{B} = \frac{24}{m^2},\ \text{C} = \frac{96}{5m^3},\ \text{D} = \frac{64}{3m^4} \text{ nearly, &c.}$$

$$\text{Hence } z = \frac{8}{m}x^{\frac{3}{2}} - \frac{24}{m^2}x^2 + \frac{96}{5m^3}x^{\frac{5}{2}} + \frac{64}{3m^4}x^3 \text{ &c.}$$

$$\text{Or } z = \frac{8}{m}x^{\frac{3}{2}} \text{ nearly.}$$

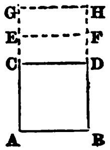
But, by the first process, when $x = 3$, $z = .886$; which substituted for them, we have $z = .886$, and the series $= 1.63$; therefore the correct fluents are

$$z - .886 = -1.63 + \frac{8}{m}x^{\frac{3}{2}} - \frac{24}{m^2}x^2 \text{ &c.}$$

$$\text{or } z + .744 = \frac{8}{m}x^{\frac{3}{2}} - \frac{24}{m^2}x^2 \text{ &c.}$$

And when $z = 3 = \text{AC}$, it gives $x = 6.369$ for the height of the tide without when the ditches are filled to the top of the sluice, or 3 feet high; which answers to $3^{\text{h}}\ 11'\ 4''$.

Lastly, to find the time of rising the remaining 3 feet above the top of the sluice; let



$x = \text{CG}$ the height of the tide above CD,
$z = \text{CE}$ ditto in the ditches above CD;
and the other dimensions as before.
Then $\sqrt{g} : \sqrt{\text{EG}} :: 2g : 2\sqrt{g}\,(x-z) =$ the velocity with which the water runs through the whole sluice AD; conseq. $\text{AD} \times 2\sqrt{g}\,(x-z) = 18\sqrt{g}\,(x-z)$ is the quantity per second running through the sluice, and $\frac{18\sqrt{g}}{\text{A}}(x-z) = v$ the velocity of z, or the rise of the water in the ditches, per second;

hence $v : \dot{x} :: 1'' : \dot{t} = \frac{\dot{x}}{v} = \frac{A}{18\sqrt{g}} \times \frac{\dot{x}}{\sqrt{(x-z)}} = 1800\dot{z}$, and $m\dot{z} = \dot{x}$ $\sqrt{(x-z)}$ is the fluxional equation; where $m = \frac{A}{180^2\sqrt{g}} = \frac{3200}{2079}$

To find the fluent,

Assume $z = Ax^{\frac{3}{2}} + Bx^{\frac{4}{2}} + Cx^{\frac{5}{2}} + Dx^{\frac{6}{2}}$ &c.

Then $x - z = x - Ax^{\frac{3}{2}} - Bx^{\frac{4}{2}} - Cx^{\frac{5}{2}}$ &c.

$$\dot{x}\sqrt{(x-z)} = x^{\frac{1}{2}}\dot{x} - \frac{A}{2}x^{\frac{2}{2}}\dot{x} - \frac{A^2+4B}{8}x^{\frac{3}{2}}\dot{x} \text{ &c.}$$

$$m\dot{z} = \tfrac{3}{2}nAx^{\frac{1}{2}}\dot{x} + \tfrac{4}{2}nBx^{\frac{2}{2}}\dot{x} + \tfrac{5}{2}nCx^{\frac{3}{2}}\dot{x} \text{ &c.}$$

Then equating the like term, gives

$$A = \frac{2}{3n},\ B = \frac{-1}{6n^2},\ C = \frac{1}{90n^3},\ D = \frac{-1}{810n^4},\ \text{&c.}$$

Hence $z = \frac{2}{3n}x^{\frac{3}{2}} - \frac{1}{6n^2}x^2 + \frac{1}{90n^3}x^{\frac{5}{2}} - \frac{1}{810n^4}x^3$ &c.

But by the second case, when $z = 0$, $x = 3.369$, which being used in the series, it is 1.936; therefore the correct fluent is $z = -1.936 + \frac{2}{3n}x^{\frac{3}{2}} - \frac{1}{6n^2}x^2$ &c. And when $z = 3$, $x = 7$; the heights above the top of the sluice, answering to 6 and 10 feet above the bottom of the ditches. That is, for the water to rise to the height of 6 feet within the ditches, it is necessary for the tide to rise to 10 feet without, which just answers to 5 hours; and so long it would take to fill the ditches 6 feet deep with water, their horizontal area being 200,000 square feet.

Further, when $x = 6$, then $z = 2.117$ the height above the top of the sluice; to which add 3, the heigth of the sluice, and the sum 5.117, is the depth of water in the ditches in $4\frac{1}{2}$ hours, or when the tide has risen to the height of 9 feet without the ditches.

HYDRAULIC AND OTHER TABLES.

TABLES

FOR FACILITATING CALCULATIONS

DAILY REQUIRED BY

AN ENGINEER,

WITH AN

APPENDIX OF TIDE TABLES.

BY NATHANIEL BEARDMORE,

CIVIL ENGINEER.

LONDON:

PRINTED BY WATERLOW AND SONS, CARPENTERS' HALL,

LONDON WALL.

1851.

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TABLE OF DISCHARGE FOR VARIOUS HEADS.

.02 to .80 Feet.

Column B, gives the natural or theoretic velocity in feet, per minute, acquired by water, or any other body, falling at the several heights in the column A.

Column C, gives the effective velocity of water passing through orifices of the form of the vena contracta—through bridges well constructed—through ordinary sluices with good side walls, and for very large sluices—through wide openings whose bottom is level with that of the reservoir. This column also gives the discharge through vertical pipes and narrow ill-built bridges, by deducting 1-9th from the product.

Column D, gives the effective velocity of water passing through sluices without side walls, such as used commonly upon mill-streams and rivers, undershot wheel-gates and canal-locks.

Rule.—Multiply the area of the orifice, in feet, by the discharge opposite the given height, either in column C or D, according to the nature of the case. See also page 1—2 for further uses.

A Head of Water.	B Natural Velocity.	C Effective Velocity.	D Effective Velocity.	A Head of Water.	B Natural Velocity.	C Effective Velocity.	D Effective Velocity.
Feet.	Feet per minute.	Feet per minute.	Feet per minute.	Feet.	Feet per minute.	Feet per minute.	Feet per minute.
				.41	308.48	288.0	192.1
.02	67.96	63.7	42.4	.42	312.33	291.6	194.4
.03	83.38	77.8	51.9	.43	316.04	295.1	196.7
.04	96.40	90.0	60.0	.44	319.56	298.3	199.0
.05	107.72	100.3	67.0	.45	323.42	301.9	201.2
.06	118.09	110.2	73.4	.46	326.79	305.1	203.4
.07	127.49	118.8	79.3	.47	330.41	308.5	205.6
.08	136.40	127.3	84.8	.48	334.02	311.8	207.8
.09	144.60	135.0	90.0	.49	337.40	315.0	210.0
.10	**152.31**	**142.2**	**94.8**	**.50**	**340.77**	**318.1**	**212.1**
.11	159.54	148.9	99.4	.51	344.15	321.3	214.2
.12	166.77	155.7	103.9	.52	347.52	324.4	216.3
.13	173.52	162.0	108.1	.53	350.89	327.6	218.4
.14	180.27	168.3	112.2	.54	354.27	330.7	220.4
.15	186.53	174.1	116.1	.55	357.16	333.7	222.5
.16	192.80	180.0	120.0	.56	360.53	336.6	224.5
.17	198.58	185.4	123.6	.57	363.91	339.7	226.5
.18	204.37	190.8	127.2	.58	367.04	342.7	228.4
.19	210.15	196.2	130.7	.59	370.17	345.6	230.4
.20	**215.45**	**201.1**	**134.1**	**.60**	**373.31**	**348.5**	**232.3**
.21	220.75	206.1	137.4	.61	376.44	351.4	234.3
.22	226.06	211.0	140.7	.62	379.33	354.1	236.2
.23	231.12	215.5	143.8	.63	382.56	357.1	238.1
.24	236.18	220.5	146.9	.64	385.60	360.0	240.0
.25	241.00	225.0	150.0	.65	388.49	362.7	241.8
.26	245.82	229.5	152.9	.66	391.38	365.4	243.7
.27	250.40	233.5	155.8	.67	394.27	368.3	245.5
.28	254.98	238.0	158.7	.68	397.45	371.0	247.4
.29	259.56	242.1	161.5	.69	400.35	373.8	249.2
.30	**263.99**	**246.4**	**164.3**	**.70**	**403.24**	**376.5**	**251.0**
.31	268.33	250.5	167.0	.71	406.13	379.2	252.8
.32	272.57	254.5	169.6	.72	408.97	381.8	254.5
.33	276.67	258.4	172.3	.73	411.62	384.3	256.3
.34	281.00	262.3	174.9	.74	414.52	387.0	258.0
.35	285.10	266.2	177.4	.75	417.41	389.7	259.8
.36	289.20	270.0	180.0	.76	420.06	392.2	261.5
.37	293.05	273.6	182.4	.77	422.71	394.6	263.2
.38	296.91	277.3	184.9	.78	425.60	397.3	264.9
.39	300.77	280.9	187.3	.79	428.50	400.0	266.6
.40	**304.62**	**284.6**	**189.7**	**.80**	**430.91**	**402.3**	**268.3**

TABLE OF DISCHARGE FOR VARIOUS HEADS.

.81 to 250. Feet.

A Head of Water.	B Natural Velocity.	C Effective Velocity.	D Effective Velocity.	A Head of Water.	B Natural Velocity.	C Effective Velocity.	D Effective Velocity.
Feet.	Feet per minute.	Feet per minute.	Feet per minute.	Feet.	Feet per minute.	Feet per minute.	Feet per minute.
.81	433.80	405.00	270.00	7.25	1298.02	1211.8	807.9
.82	436.21	407.5	271.6	7.50	1320.20	1232.5	821.7
.83	439.10	409.9	273.3	7.75	1341.89	1252.8	835.2
.84	441.51	412.4	274.9	8.00	1363.09	1272.6	848.4
.85	444.40	414.9	276.6	8.25	1384.30	1292.4	861.6
.86	446.81	417.1	278.2	8.50	1405.03	1311.7	874.5
.87	449.56	420.6	279.8	8.75	1425.75	1331.1	887.4
.88	452.11	422.1	281.4	9.00	1446.00	1350.0	900.0
.89	454.52	424.3	282.9	9.25	1465.76	1368.4	912.3
.90	**457.22**	**426.9**	**284.5**	**9.50**	**1485.52**	**1386.9**	**924.6**
.91	459.83	429.3	286.1	9.75	1504.80	1404.9	936.6
.92	462.24	431.5	287.7	10.00	1524.08	1422.9	948.6
.93	464.65	433.8	289.2	10.25	1543.36	1440.9	960.6
.94	467.06	436.3	290.8	10.50	1561.68	1458.0	972.0
.95	469.76	438.6	292.3	10.75	1580.47	1475.5	983.7
.96	472.21	440.8	293.9	11.00	1598.79	1492.6	995.1
.97	474.77	443.2	295.4	11.25	1616.62	1509.3	1006.2
.98	477.18	445.5	296.9	11.50	1634.46	1525.9	1017.3
.99	479.59	447.7	298.4	11.75	1652.29	1542.6	1028.4
1.00	**482.00**	**450.0**	**300.0**	**12.00**	**1669.648**	**1558.8**	**1039.2**
1.10	505.62	472.0	314.6	12.25	1687.00	1575.0	1050.0
1.20	527.79	492.7	328.6	12.50	1703.87	1590.7	1060.5
1.25	538.87	503.1	335.4	12.75	1721.22	1606.9	1071.3
1.30	549.58	513.0	342.0	13.00	1737.61	1622.2	1081.5
1.40	570.20	532.3	354.9	13.25	1754.48	1638.0	1092.0
1.50	590.30	551.1	367.4	13.50	1770.86	1653.3	1102.2
1.60	609.73	569.2	379.5	13.75	1787.25	1668.6	1112.4
1.70	628.52	586.8	391.1	14.00	1803.64	1683.9	1122.6
1.75	637.68	595.3	396.8	14.25	1819.55	1698.7	1132.5
1.80	**646.60**	**603.7**	**402.5**	**14.50**	**1835.45**	**1713.60**	**1142.4**
1.90	664.19	620.1	413.5	14.75	1850.88	1728.00	1152.0
2.00	681.55	636.3	424.2	15.00	1866.78	1742.85	1161.9
2.10	699.86	652.5	434.7	15.50	1897.63	1771.65	1181.1
2.20	714.80	667.3	444.9	16.00	1928.00	1800.00	1200.3
2.25	723.00	675.0	450.0	16.50	1957.88	1 27.90	1218.6
2.30	730.95	682.4	454.9	17.00	1987.28	1855.35	1236.9
2.40	746.62	697.0	464.7	17.50	2016.20	1882.35	1254.9
2.50	762.04	711.4	474.3	18.00	2045.12	1909.35	1272.9
2.60	776.98	725.4	483.7	18.50	2073.08	1935.45	1290.3
2.70	**791.92**	**739.3**	**493.9**	**19.00**	**2101.03**	**1961.55**	**1307.7**
2.75	799.15	746.1	497.5	19.50	2128.51	2007.20	1324.8
2.80	806.38	752.8	502.0	20.00	2155.50	2012.40	1341.6
2.90	820.84	766.3	510.9	25.00	2410.00	2250.00	1500.0
3.00	834.82	779.5	519.6	30.00	2639.91	2464.65	1643.1
3.25	869.04	811.3	540.9	35.00	2851.51	2662.20	1774.8
3.50	901.82	841.9	561.3	40.00	3048.16	2845.80	1897.2
3.75	933.15	871.2	580.8	45.00	3233.25	3018.60	2012.4
4.00	964.00	900.0	600.0	50..0	3408.22	3181.95	2121.3
4.25	993.40	927.4	618.3	55.00	3574.51	3337.2	2224.8
4.50	**1022.32**	**954.4**	**636.3**	**60.00**	**3733.57**	**3485.7**	**2323.8**
4.75	1050.76	981.0	654.0	65.00	3885.88	3627.9	2418.6
5.00	1077.75	1006.2	670.8	70.00	4032.41	3764.70	2509.8
5.25	1104.26	1030.9	687.3	75.00	4174.12	3897.0	2598.0
5.50	1130.29	1055.2	703.5	80.00	4311.00	4024.80	2683.2
5.75	1155.83	1079.1	719.4	85.00	4443.55	4148.5	2765.7
6.00	1180.42	1102.0	734.7	90.00	4572.73	4269.1	2846.1
6.25	1205.00	1125.0	750.0	95.00	4698.05	4386.1	2924.1
6.50	1228.62	1149.0	764.7	100.00	4820.00	4500.0	3000.0
6.75	1252.23	1169.1	779.4	200.00	6816.44	6363.90	4242.6
7.00	**1275.37**	**1190.7**	**793.8**	**250.00**	**7615.0**	**7110.00**	**4740.0**

WEIRS OR OVERFALLS.—Table 2

DISCHARGE,

IN CUBIC FEET PER MINUTE FOR ONE FOOT IN LENGTH.

Rule.—*Multiply the Quantity in the Table, opposite the given Depth, by the length of the Weir in Feet; using Decimals for Fractional Parts.*

Depth falling over.	Discharge per Minute.	Depth falling over.	Discharge per Minute.	Depth falling over.	Discharge per Minute.
Feet.	Cubic Feet.	Feet.	Cubic Feet.	Feet.	Cubic Feet.
		.51	77.53	1.01	217.21
.02	0.60	.52	79.87	1.02	220.42
.03	1.10	.53	82.22	1.03	223.63
.04	1.70	.54	84.56	1.04	226.84
.05	2.37	.55	86.69	1.05	230.05
.06	3.13	.56	89.24	1.06	233.47
.07	3.93	.57	91.59	1.07	236.68
.08	4.82	.58	93.93	1.08	240.32
.09	5.75	.59	96.49	1.09	243.53
.10	**6.73**	**.60**	**98.83**	**1.10**	**246.95**
.11	7.77	.61	101.38	1.11	250.38
.12	8.84	.62	103.94	1.12	253.80
.13	9.97	.63	106.50	1.13	257.23
.14	11.14	.64	109.05	1.14	260.65
.15	12.35	.65	111.61	1.15	264.07
.16	13.63	.66	114.17	1.16	267.50
.17	14.91	.67	116.72	1.17	270.92
.18	16.18	.68	119.28	1.18	274.35
.19	17.46	.69	122.05	1.19	277.77
.20	**18.95**	**.70**	**124.60**	**1.20**	**281.19**
.21	20.44	.71	127.37	1.21	284.83
.22	21.93	.72	130.14	1.22	288.26
.23	23.43	.73	132.91	1.23	291.89
.24	24.92	.74	135.46	1.24	295.32
.25	26.62	.75	138.88	1.25	298.95
.26	28.11	.76	141.66	1.26	302.59
.27	29.82	.77	144.45	1.27	306.23
.28	31.60	.78	147.23	1.28	309.87
.29	33.22	.79	150.22	1.29	313.51
.30	**34.93**	**.80**	**153.00**	**1.30**	**317.14**
.31	36.63	.81	156.00	1.31	320.57
.32	38.34	.82	158.78	1.32	324.42
.33	40.25	.83	161.78	1.33	328.23
.34	41.17	.84	164.56	1.34	331.70
.35	43.88	.85	167.77	1.35	335.34
.36	45.00	.86	170.55	1.36	339.19
.37	47.71	.87	173.55	1.37	343.04
.38	49.84	.88	176.55	1.38	346.89
.39	51.76	.89	179.54	1.39	350.74
.40	**53.67**	**.90**	**182.54**	**1.40**	**354.38**
.41	55.80	.91	185.75	1.41	358.02
.42	57.93	.92	188.74	1.42	361.87
.43	60.06	.93	191.74	1.43	365.94
.44	62.19	.94	194.95	1.44	369.79
.45	64.32	.95	197.95	1.45	373.64
.46	66.45	.96	200.94	1.46	377.28
.47	68.58	.97	204.37	1.47	381.13
.48	70.71	.98	207.58	1.48	384.98
.49	73.05	.99	210.79	1.49	389.65
.50	**75.19**	**1.00**	**214.00**	**1.50**	**392.90**

WEIRS OR OVERFALLS.—Table 2

DISCHARGE,

IN CUBIC FEET PER MINUTE FOR ONE FOOT IN LENGTH.

Rule.—*Multiply the Quantity in the Table, opposite the given Depth, by the length of the Weir in Feet; using Decimals for Fractional Parts.*

Depth falling over.	Discharge per Minute.	Depth falling over.	Discharge per Minute.	Depth falling over.	Discharge per Minute.
Feet.	Cubic Feet.	Feet.	Cubic Feet.	Feet.	Cubic Feet.
1.51	396.97	2.01	609.90	2.51	850.65
1.52	401.03	2.02	614.18	2.52	855.78
1.53	404.89	2.03	618.89	2.53	860.70
1.54	408.95	2.04	623.38	2.54	866.27
1.55	412.80	2.05	627.66	2.55	871.40
1.56	416.87	2.06	632.58	2.56	876.54
1.57	420.94	2.07	637.50	2.57	881.46
1.58	425.00	2.08	641.78	2.58	886.60
1.59	429.07	2.09	646.28	2.59	891.73
1.60	**433.13**	**2.10**	**651.20**	**2.60**	**896.87**
1.61	437.20	2.11	655.69	2.61	902.01
1.62	441.26	2.12	659.40	2.62	907.14
1.63	445.33	2.13	664.90	2.63	912.92
1.64	449.18	2.14	669.82	2.64	918.06
1.65	453.25	2.15	674.53	2.65	923.19
1.66	457.10	2.16	679.02	2.66	928.33
1.67	461.59	2.17	683.94	2.67	933.68
1.68	465.88	2.18	688.44	2.68	939.46
1.69	470.16	2.19	692.71	2.69	943.95
1.70	**474.44**	**2.20**	**698.07**	**2.70**	**949.30**
1.71	478.29	2.21	702.77	2.71	954.44
1.72	482.57	2.22	707.70	2.72	959.79
1.73	486.85	2.23	712.40	2.73	965.14
1.74	491.13	2.24	717.11	2.74	970.27
1.75	495.41	2.25	722.25	2.75	975.62
1.76	499.69	2.26	726.74	2.76	980.97
1.77	503.97	2.27	731.45	2.77	986.32
1.78	508.25	2.28	736.59	2.78	992.31
1.79	512.53	2.29	741.29	2.79	997.02
1.80	**516.81**	**2.30**	**746.00**	**2.80**	**1,002.32**
1.81	521.09	2.31	751.35	2.81	1,007.72
1.82	525.37	2.32	756.06	2.82	1,013.29
1.83	529.65	2.33	760.77	2.83	1,018.64
1.84	533.93	2.34	766.12	2.84	1,023.99
1.85	538.42	2.35	770.82	2.85	1,029.55
1.86	542.92	2.36	775.53	2.86	1,034.90
1.87	546.98	2.37	780.67	2.87	1,040.46
1.88	551.48	2.38	785.80	2.88	1,045.81
1.89	555.97	2.39	790.51	2.89	1,051.38
1.90	**560.25**	**2.40**	**795.44**	**2.90**	**1,056.94**
1.91	564.74	2.41	800.36	2.91	1,062.29
1.92	569.02	2.42	805.28	2.92	1,067.86
1.93	573.52	2.43	810.63	2.93	1,073.42
1.94	578.22	2.44	815.55	2.94	1,078.34
1.95	582.50	2.45	820.49	2.95	1,083.91
1.96	587.21	2.46	825.40	2.96	1,089.47
1.97	591.49	2.47	830.32	2.97	1,095.03
1.98	596.20	2.48	835.88	2.98	1,100.60
1.99	600.48	2.49	840.80	2.99	1,106.38
2.00	**605.19**	**2.50**	**845.73**	**3.00**	**1,111.94**

VELOCITIES OF RIVERS.—Table 3

TABLE OF SURFACE, MEAN & BOTTOM VELOCITIES OF STREAMS, RIVERS AND TIDAL ESTUARIES.

From 5 to 200 Feet per Minute.

Rule.—*The first column represents the average surface velocities at the middle of a river. Any corresponding mean velocity, when multiplied by the area, will give the discharge in cubic feet, per minute. The bottom velocities represent the action on the sides and bottom of any stream, pipe, or culvert, whose mean velocity is known.*

Note.—For velocities in inches, per second, divide the tabular numbers by 5.
For miles per hour, multiply the tabular numbers by .01136.

Surface Velocity.	Mean Velocity.	Bottom Velocity.	Surface Velocity.	Mean Velocity.	Bottom Velocity.
Feet ℔ Minute.	Feet ℔ Minute.	Feet ℔ Minute.	Feet ℔ Minute.	Feet ℔ Minute.	Feet ℔ Minute.
			102.5	82.35	62.2
5.	2.50	.0	105.	84.60	64.2
7.5	3.90	.3	107.5	86.80	66.1
10.	5.45	.9	110.	89.05	68.1
12.5	7.10	1.7	112.5	91.30	70.1
15.	8.85	2.7	115.	93.55	72.1
17.5	10.65	3.8	117.5	95.75	74.0
20.	**12.50**	**5.0**	**120.**	**98.00**	**76.0**
22.5	14.40	6.3	122.5	100.25	78.0
25.	16.35	7.7	125.	102.50	80.0
27.5	18.30	9.1	127.5	104.75	82.0
30.	20.25	10.5	130.	107.00	84.0
32.5	22.05	12.0	132.5	109.25	86.0
35.	24.30	13.6	135.	111.55	88.1
37.5	26.30	15.1	137.5	113.80	90.1
40.	**28.35**	**16.7**	**140.**	**116.05**	**92.1**
42.5	30.45	18.4	142.5	118.30	94.1
45.	32.50	20.0	145.	120.60	96.2
47.5	34.60	21.7	147.5	122.85	98.2
50.	36.70	23.4	150.	125.15	100.3
52.5	38.80	25.1	152.5	127.40	102.3
55.	40.95	26.9	155.	129.65	104.3
57.5	43.05	28.6	157.5	131.95	106.4
60.	**45.20**	**30.4**	**160.**	**134.20**	**108.4**
62.5	47.35	32.2	162.5	136.50	110.5
65.	49.50	34.0	165.	138.80	112.6
67.5	51.65	35.8	167.5	141.05	114.6
70.	53.80	37.6	170.	143.35	116.7
72.5	55.95	39.4	172.5	145.65	118.8
75.	58.15	41.3	175.	147.95	120.9
77.5	60.30	43.1	177.5	150.20	122.9
80.	**62.50**	**45.0**	**180.**	**152.50**	**125.0**
82.5	64.70	46.7	182.5	154.80	127.1
85.	66.90	48.8	185.	157.10	129.2
87.5	69.10	50.7	187.5	159.40	131.3
90.	71.30	52.6	190.	161.70	133.4
92.5	73.50	54.5	192.5	164.00	135.5
95.	75.70	56.4	195.	166.30	137.6
97.5	77.95	58 4	197.5	168.60	139.7
100.	**80.15**	**60.3**	**200.**	**170.90**	**141.8**

VELOCITIES OF RIVERS.—TABLE 3

TABLE OF SURFACE, MEAN & BOTTOM VELOCITIES OF STREAMS, RIVERS AND TIDAL ESTUARIES.

From 202.5 to 950 Feet per Minute.

NOTE.—Bottom velocities—

30 feet per minute will not disturb clay with sand and stones.
40 „ „ will sweep along coarse sand.
60 „ „ „ fine gravel.
120 „ „ „ rounded pebbles.
180 „ „ „ angular stones.

Surface Velocity.	Mean Velocity.	Bottom Velocity.	Surface Velocity.	Mean Velocity.	Bottom Velocity.
Feet ⅌ Minute.	Feet ⅌ Minute.	Feet ⅌ Minute.	Feet ⅌ Minute.	Feet ⅌ Minute.	Feet ⅌ Minute.
202.5	173.20	143.9	305	268.4	231.9
205.0	175.50	146.0	310	273.1	236.3
207.5	177.80	148.1	315	277.8	240.6
210.0	180.10	150.2	320	282.5	245.0
212.5	182.40	152.3	325	287.2	249.4
215.0	184.75	154.5	330	291.9	253.8
217.5	187 05	156.6	335	296.6	258.2
220.0	**189.35**	**158.7**	**340**	**301.2**	**262.5**
222.5	191.65	160.8	345	305.9	266.9
225.0	193.95	162.9	350	310.6	271.3
227.5	196.30	165.1	355	315.3	275.7
230.0	198.60	167.2	360	320.1	280.2
232.5	200.90	169.3	365	324.8	284.6
235.0	203.25	171.5	370	329.5	289.0
237.5	205.55	173.6	375	334.2	293.4
240.0	**207.85**	**175.7**	**380**	**338.9**	**297.8**
242.5	210.20	177.9	385	343.6	302.3
245.0	212.50	180.0	390	348.3	306.7
247.5	214.85	182.2	395	353.0	311.1
250.0	217.15	184.3	400	357.8	315.6
252.5	219.50	186.5	405	362.5	320.0
255.0	221.80	188.6	410	367.2	324.5
257.5	224.15	190.8	415	371.9	328.9
260.0	**226.45**	**192.9**	**420**	**376.7**	**333.4**
262.5	228.80	195.1	425	381.4	337.8
265.0	231.10	197.2	430	386.1	342.3
267.5	233.45	199.4	435	390.8	346.7
270.0	235.75	201.5	440	395.6	351.2
272.5	238.10	203,7	445	400.3	355.7
275.0	240.45	205.9	450	405.1	360.2
277.5	242.75	208.0	500	452.5	405.0
280.0	**245.10**	**210.1**	**550**	**500.0**	**450.1**
282.5	247.45	212.4	600	547.7	495.5
285.0	249.75	214.5	650	595.5	541.0
287.5	252.10	216.7	700	643.3	586.7
290.0	254.45	218.9	750	691.2	632.5
292.5	256.75	221.0	800	739.2	678.5
295.0	259.10	223.2	850	787.3	724.6
297.5	261.45	225.4	900	835.4	770.8
300.0	**263.75**	**227.5**	**950**	**883.6**	**817.2**

TABLE OF DISCHARGE AND VELOCITIES,

IN CUBIC AND LINEAL FEET PER MINUTE,

For Cuts of any kind at the Specified Rates of Fall per Mile, and with the Depths of Water and Bottom Widths stated in the First Column.

With Slopes of 2 to 1 throughout.

For the Discharge and Velocity of any Cut having a Fall per Mile of ..	In.	Take twice the Discharge & Velocity from the Columns respectively of	In.	For the Discharge and Velocity of any Cut having a Fall per Mile of ..	In.	Take half the Discharge and Velocity from the Columns respectively of	In.
	8		2		½		2
	12		3		¾		3
	16		4		1		4
	20		5		1¼		5
	24		6		1½		6
	36		9		2¼		9

FALL.		2 inches. per mile.		3 inches. per mile.		4 inches. per mile.		5 inches. per mile.		6 inches. per mile.		9 inches. per mile.	
	Bottom Widths Feet.	Discharge cubic feet.	Vel. feet.	Discharge cubic feet.	Vel. feet.	Discharge cubic feet.	Vel. feet.	Discharge cubic feet.	Vel. feet.	Discharge cubic feet.	Vel. feet.	Discharge cubic feet.	Vel. feet.
Depth 1.5 Feet.	3	275	30.6	336	37.4	389	43.2	435	48.3	476	52.9	578	64.3
	4	329	31.4	404	38.5	466	44.4	521	49.6	571	54.4	698	66.5
	5	385	32.1	471	39.3	543	45.3	609	50.8	666	55.5	811	67.6
	6	441	32.7	540	40.0	624	46.2	698	51.7	764	56.6	925	69.3
	7	498	33.2	609	40.6	703	46.9	787	52.5	858	57.2	1056	70.4
	8	554	33.6	680	41.2	784	47.5	876	53.1	960	58.2	1171	70.9
	9	612	34.0	749	41.6	866	48.1	966	53.7	1056	58.7	1296	72.0
	10	669	34.3	817	41.9	946	48.5	1057	54.2	1156	59.3	1416	72.6
	12	783	34.8	958	42.6	1007	49.2	1237	55.0	1354	60.2	1658	73.7
	14	897	35.2	1099	43.1	1270	49.8	1415	55.5	1555	61.0	1907	74.8
Depth 2.0 Feet.	3	477	34.1	585	41.8	677	48.4	759	54.2	831	59.4	1016	72.6
	4	563	35.2	686	42.9	798	49.9	888	55.5	976	61.0	1196	74.8
	5	642	35.7	794	44.1	918	51.0	1020	56.6	1118	62.1	1375	76.4
	6	726	36.3	900	45.0	1034	51.7	1114	57.2	1264	63.2	1556	77.8
	7	820	37.3	1003	45.6	1161	52.8	1295	58.8	1414	64.3	1729	78.6
	8	897	37.4	1109	46.2	1279	53.3	1425	59.4	1569	65.4	1912	79.7
	9	985	37.9	1214	46.7	1401	53.9	1557	59.9	1716	66.0	2101	80.8
	10	1081	38.6	1324	47.3	1523	54.4	1702	60.8	1862	66.5	2279	81.4
	12	1245	38.9	1529	47.8	1750	55.0	1968	61.5	2163	67.6	2656	83.0
	14	1429	39.7	1742	48.4	2019	56.1	2257	62.7	2473	68.7	3047	84.1
Depth 2.5 Feet.	3	754	37.7	922	46.1	1066	53.3	1176	58.8	1298	64.9	1594	79.7
	4	868	38.6	1064	47.3	1228	54.6	1372	61.0	1496	66.5	1842	81.9
	5	985	39.4	1207	48.3	1387	55.5	1552	62.1	1705	68.2	2090	83.6
	6	1103	40.1	1353	49.2	1556	56.6	1738	63.2	1905	69.3	2343	85.2
	7	1221	40.7	1497	49.9	1731	57.7	1929	64.3	2112	70.4	2589	86.3
	8	1339	41.2	1644	50.6	1894	58.3	2109	64.9	2323	71.5	2840	87.4
	9	1463	41.8	1561	51.2	2058	58.8	2310	66.0	2520	72.0	3097	88.5
	10	1582	42.2	1938	51.7	2227	59.4	2493	66.5	2741	73.1	3360	89.6
	12	1823	42.9	2235	52.6	2571	60.5	2873	67.6	3153	74.2	3880	91.3
	14	2071	43.6	2536	53.4	2926	61.6	3263	68.7	3576	75.3	4389	92.4

ARTERIAL DRAINS, NEW CUTS AND RIVERS—Table 4

DISCHARGE AND VELOCITIES

IN CUBIC AND LINEAL FEET PER MINUTE.

At the following Rates of Fall.

FALL.		2 inches per mile.		3 inches per mile.		4 inches per mile.		5 inches per mile.		6 inches per mile.		9 inches per mile.	
	Bottom widths. Feet.	Discharge cubic feet.	Vel. feet.	Discharge cubic feet.	Vel. feet.	Discharge cubic feet.	Vel. feet.	Discharge cubic feet.	Vel. feet.	Discharge cubic feet.	Vel. feet.	Discharge cubic feet.	Vel. feet.
Depth 3.00 feet.	4	1245	41.5	1527	50.9	1764	58.8	1962	65.4	2160	72.0	2640	88.0
	6	1551	43.1	1904	52.9	2196	61.0	2455	68.2	2812	74.8	3287	91.3
	8	1865	44.4	2284	54.4	2633	62.7	2931	69.8	3234	77.0	3948	94.0
	10	2179	45.4	2664	55.5	3062	63.8	3432	71.5	3773	78.6	4617	96.2
	12	2495	46.2	3056	56.6	3504	64.9	3920	72.6	4304	79.7	5286	97.9
	14	2814	46.9	3432	57.2	3960	66.0	4622	73.7	4848	80.8	5940	99.0
	16	3135	47.5	3847	58.3	4428	67.1	4929	74.8	5405	81.9	6639	100.6
	18	3456	48.0	4233	58.8	4867	67.6	5465	75.9	5976	83.0	7322	101.7
	20	3783	48.5	4617	59.2	5319	68.2	5959	76.4	6521	83.6	8018	102.8
	25	4594	49.4	5626	60.5	6491	69.8	7263	78.1	7923	85.2	9718	104.5
Depth 3.50 feet.	6	2093	46.0	2552	56.1	2953	64.9	3303	72.6	3626	79.7	4427	97.3
	8	2483	47.3	3029	57.7	3491	66.5	3927	74.8	4273	81.4	5255	100.1
	10	2656	48.3	3534	59.4	4052	68.1	4516	75.9	4968	83.5	6087	102.3
	12	3271	49.2	3983	59.9	4608	69.3	5153	77.5	5672	85.3	6942	104.4
	14	3675	50.0	4483	61.0	5174	70.4	5777	78.6	6350	86.4	7754	105.5
	16	4073	50.6	4999	61.1	5755	71.5	6416	79.7	7043	87.5	8630	107.2
	18	4480	51.2	5486	62.7	6300	72.0	7070	80.8	7752	88.6	9476	108.3
	20	4885	51.7	5972	63.2	6908	73.1	7692	81.4	8420	89.1	10,338	109.4
	25	5913	52.8	7201	64.3	8310	74.2	9296	83.0	10,225	91.3	12,499	111.0
	30	6915	53.4	8404	64.9	9751	75.3	10,890	84.1	11,966	92.4	14,615	113.3
Depth 4.00 feet.	6	2565	45.8	3326	59.4	3847	68.7	4278	76.4	4710	84.1	5757	102.8
	8	3187	49.8	3904	61.0	4505	70.4	5030	78.6	5530	86.4	6752	105.5
	10	3672	51.0	4478	62.2	5184	72.0	5781	80.3	6336	88.0	7718	107.2
	12	4160	52.0	5104	63.8	5848	73.1	6552	81.9	7216	90.2	8800	110.3
	14	4646	52.8	5658	64.3	6529	74.2	7304	83.0	8034	91.3	9829	111.7
	16	5126	53.4	6278	65.4	7229	75.3	8073	84.1	8870	92.4	10,925	113.8
	18	5616	54.0	6864	66.0	7945	76.4	8871	85.3	9724	93.5	11,897	114.4
	20	6104	54.5	7448	66.5	8624	77.0	9609	85.8	10,528	94.0	12,936	115.5
	25	7339	55.6	9002	68.2	10,375	78.6	11,616	88.0	12,698	96.2	15,615	118.3
	30	8527	56.1	10,533	69.3	12,114	79.7	13,543	89.1	14,865	97.8	18,225	119.9
Depth 4.50 feet.	8	4005	52.3	4880	63.8	5638	73.7	6303	82.4	6946	90.8	8,500	111.1
	10	4565	53.4	5591	65.4	6438	75.3	7190	84.1	7800	92.4	9,687	113.3
	12	5140	54.4	6284	66.5	7276	77.0	8108	85.8	8883	94.0	10,915	115.5
	14	5692	55.0	6996	67.6	8052	77.8	9056	87.5	9905	95.7	12,130	117.2
	16	6311	56.1	7728	68.7	8842	78.6	9967	88.6	10,890	96.8	13,365	118.8
	18	6,864	56.5	8408	69.2	9683	79.7	10,825	89.1	11,895	97.9	14,569	119.9
	20	7,464	57.2	9109	69.8	10,544	80.8	11,771	90.2	12,920	99.0	15,790	121.0
	25	8,920	58.3	10,939	71.5	12,622	82.5	14,121	92.3	15,483	101.2	18,926	123.7
	30	10,424	59.4	12,741	72.6	14,672	83.6	16,409	93.5	18,041	102.8	22,095	125.9
	35	11,860	59.9	14,592	73.7	16,770	84.7	18,850	95.2	20,572	103.9	25,265	127.6

DISCHARGE AND VELOCITIES

IN CUBIC AND LINEAL FEET PER MINUTE,

At the following Rates of Fall.

FALL.		2 inches. per mile.		3 inches. per mile.		4 inches. per mile.		5 inches. per mile.		6 inches per mile.		9 inches per mile.	
	Bottom widths. Feet.	Dis-charge cubic feet.	Vel. feet.	Dis-charge cubic feet.	Vel. feet.	Dis-charge cubic feet.	Vel. feet.	Dis-charge cubic feet.	Vel. feet.	Dis-charge cubic feet.	Vel. feet.	Dis-charge cubic feet.	Vel. feet.
Depth 5.00 feet.	8	4896	54.	5985	66	6930	77	7767	86	8505	94	10395	115
	10	5560	55.	6810	68	7860	78	8800	88	9630	96	11830	118
	12	6215	56.	7612	69	8833	80	9867	90	10769	98	13244	120
	14	6924	57.	8448	70	9768	81	10884	91	11952	100	14628	122
	16	7579	59.	9295	71	10725	82	12012	92	13156	101	16055	123
	18	8232	58	10080	72	11704	83	13090	93	14322	102	17556	125
	20	8985	60	10965	73	12615	84	14100	94	15510	103	18960	126
	25	10675	61	12985	74	14997	86	16835	96	18462	105	22610	129
	30	12320	62	15180	76.	17480	87	19580	98	21440	107	26280	131
	35	14107	63	17325	77	19912	88	22275	99	24480	109	29947	133
Depth 6.00 feet.	10	7906	60	9649	73	11180	85	12474	94	13728	104	16830	127
	12	8784	61	10771	75	12441	86	13867	96	15192	105	18604	129
	14	9609	62	11840	76	13650	87	15272	98	16723	107	20498	131
	16	10533	63	12936	77	14884	88	16732	99	18276	109	22344	133
	18	11394	63	13950	77	16146	90	18018	100	19803	110	24246	135
	20	12249	64	15091	78	17433	91	19430	101	21331	111	26150	136
	25	14518	65	17826	80	20512	92	22954	103	25152	113	30880	139
	30	16758	66	20512	81	23688	94	26586	105	29106	115	35758	142
	35	19063	67	23265	82	26987	96	30230	107	33022	117	40467	143
	40	21278	68	26083	83	30201	97	33789	108	37065	110	45302	145
Dep h 7.00 feet.	10	10718	64	13120	78.	15170	90	17001	101	1 564	119	22713	135
	12	11811	65	14396	79.	16707	92	18709	103	20511	113	24988	137
	14	12936	66	15836	81.	18326	93	20462	104	22402	114	27479	140
	16	13965	66	17199	82.	19845	94	22155	105	24255	115	29799	142
	18	15142	67	18457	82.	21436	95	23878	106	26252	117	32144	143
	20	16231	68	19873	83	22919	96	25622	108	28155	118	34557	145
	25	19055	70	23286	85	26863	98	30030	100	32869	120	40376	148
	30	21837	71	26765	87	30984	100	34557	112	37884	123	46415	151
	35	24696	72	30184	88	34883	102	39033	114	42737	125	52444	153
	40	27631	73	33679	89	39085	103	43659	115	47703	126	58627	155
Depth 8.00 feet.	12	15388	69	18838	84	21683	96.8	24259	108	26611	119	32636	146
	15	17310	70	21303	86	24552	99.0	27404	110	29958	121	36803	148
	20	20736	72	25372	88	29289	102	32774	114	35884	125	44035	153
	25	24173	74	29618	90	34079	104	38244	116	41820	127	51233	156
	30	27526	75	33782	92	39008	106	43534	118	47729	130	58475	159
	35	30967	76	37903	93	43941	107	49123	120	53815	132	65973	162
	40	34496	77	42112	94	48518	108	54700	122	59852	133	73158	163
	45	37820	77	46457	95	53680	110	60121	123	65733	135	80528	165
	50	41500	78	50846	96	58660	111	65630	124	71913	136	87964	166
	60	48092	79	58854	97	68217	112	76243	125	83113	137	102326	168

ARTERIAL DRAINS, NEW CUTS AND RIVERS.—Table 4a

DISCHARGE AND VELOCITIES

IN CUBIC AND LINEAL FEET PER MINUTE,

With Slopes of 3 to 1,

CHIEFLY FOR APPLICATION TO LARGE RIVERS.

(See Remarks in the *Rules for Use.*)

At the following Rates of Fall.

FALL.		2 inches per mile.		3 inches per mile.		4 inches per mile.		5 inches per mile.		6 inches per mile.	
	Bottom widths. Feet.	Discharge in cubic feet.	Vel. feet.	Discharge in cubic feet.	Vel. feet.	Discharge in cubic feet.	Vel. feet.	Discharge in cubic feet.	Vel. feet.	Discharge in cubic feet.	Vel. feet.
Depth 8 feet.	40	37,553	75	47,308	92	54,774	107	60,928	119	66,560	130
	60	52,483	78	64,310	96	73,920	110	83,328	124	90,720	135
	80	66,310	80	81,452	98	104,016	113	104,832	126	114,816	138
	100	80,748	81	98,704	99	114,080	115	126,976	128	139,872	141
	120	95,040	83	115,200	100	133,632	116	149,760	130	164,736	143
	140	108,896	83	133,824	102	154,816	118	171,872	131	188,928	144
Depth 10 feet.	40	57,750	82	70,700	101	81,200	116	91,000	130	100,100	143
	60	77,220	86	94,500	105	108,900	121	121,500	135	133,200	148
	80	96,800	88	118,800	108	136,400	124	152,900	139	167,200	152
	100	115,830	89	141,700	109	163,800	126	183,300	141	200,200	154
	120	136,050	91	166,500	111	192,000	128	214,500	143	235,500	157
	140	155,210	91	190,400	112	221,000	130	246,500	145	270,300	159
Depth 12 feet.	60	105,753	92	130,176	113	149,760	130	167,040	145	183,168	159
	80	131,683	95	161,472	116	185,136	133	207,408	149	228,288	164
	100	156,182	96	190,944	117	220,320	135	246,432	151	269,280	165
	120	183,268	98	224,640	120	258,336	138	290,160	155	318,240	170
	140	209,088	99	255,552	121	295,680	140	331,584	157	364,264	172
	160	235,200	100	286,944	122	331,632	141	371,616	158	409,248	174
Depth 16 feet.	60	177,984	103	219,456	127	254,016	147	283,392	164	301,040	180
	80	219,136	107	266,240	130	309,248	151	346,112	169	378,880	185
	100	258,112	109	314,944	133	364,672	154	407,296	172	445,206	188
	120	295,680	110	362,880	135	422,016	157	470,500	175	513,408	191
	140	336,896	112	412,090	137	475,264	158	532,416	177	583,550	194
	160	376,064	113	459,264	138	532,480	160	595,712	179	652,288	196
Depth 20 feet.	100	380,800	119	467,200	146	540,800	169	601,600	188	662,400	207
	140	488,000	122	604,000	151	696,000	174	776,000	194	852,000	213
	180	600,000	125	739,200	154	850,600	177	950,400	198	1041,600	217
	220	711,200	127	873,600	156	1008,000	180	1131,200	202	1237,600	221
	260	825,600	129	1011,200	158	1164,800	182	1305,600	204	1427,200	223
	300	936,000	130	1144,800	159	1324,800	184	1490,400	207	1627,200	226
Depth 24 feet.	140	671,616	132	824,256	162	946,380	186	1063,392	209	1165,152	229
	180	816,480	135	1003,968	166	1155,168	191	1294,272	214	1421,280	235
	220	960,096	137	1177,344	168	1359,552	194	1520,736	217	1667,904	238
	260	1115,520	140	1362,528	171	1569,696	197	1752,960	220	1928,256	242
	300	1258,848	141	1544,544	173	1776,672	199	1990,944	223	2178,432	244
	340	1304,096	142	1720,512	174	1987,488	201	2224,800	225	2432,448	246
Depth 28 feet.	200	1153,040	145	1415,456	178	1638,112	206	1828,960	230	1964,144	247
	400	2073,456	153	2547,776	188	2940,784	217	3293,136	243	3604,832	266
	600	3006,864	157	3696,336	193	4251,744	222	4768,848	249	5228,496	273
	800	3935,568	159	4851,392	196	5593,952	226	6237,504	252	6831,552	276
	1000	4917,624	162	5979,344	197	6950,608	229	7739,760	255	8468,208	279
	1200	5824,224	162	7118,496	198	8233,008	229	9167,760	255	10066,560	280

CIRCULAR CULVERTS.—TABLE 4b.

TABLE OF DISCHARGE AND VELOCITIES,

IN CUBIC AND LINEAL FEET PER MINUTE,

For Culverts or Sewers of different diameters, *not full*, but carrying Water to two several Depths and Areas specified in each case.

The use of this Table may be extended by the following Rule:—

	Ft. Ꝑ Mile.		Ft. Ꝑ Mile.
For the Discharge and Velocity of a Culvert having a fall of	8 12 16 20 24 28	Take twice the Discharge & Velocity from the Columns of	2 3 4 5 6 7
For the Discharge and Velocity of any Culvert having a fall of	¼ ½ 1 1¼ 1½ 1¾	Take half the Discharge & Velocity from the Columns of	2 3 4 5 6 7

RATE OF FALL.			2 Feet Ꝑ Mile. 1 in 2640		3 Feet Ꝑ Mile. 1 in 1760		4 Feet Ꝑ Mile. 1 in 1320		5 Feet Ꝑ Mile. 1 in 1056		6 Feet Ꝑ Mile. 1 in 880		7 Feet Ꝑ Mile. 1 in 754.3	
Dia. of Cul.	Quantity Running. Depth	Area	Dis. per Min.	Vel. per Min.	Dis. per Min.	Vel per Min.	Dis. per Min.	Vel. per Min.	Dis. per Min.	Vel. per Min.	Dis. per Min.	Vel. per Min.	Dis. per Min.	Vel. per Min.
Ft. In.	Ft. In.	Sq. Ft.	C. Ft.	Feet.	C. Ft.	Feet.	C. Ft.	Feet.	C. Ft.	Feet.	C. Ft.	Feet.	C. Ft.	Feet.
8.0	6.0	40.40	6,910	171.0	8,466	209.5	9,777	242.0	10,932	270.6	11,977	296.4	12,932	320.1
	4.0	25.13	3,911	155.6	4,782	190.3	5,529	220.0	6,178	245.8	6,772	269.5	7,312	290.9
7.0	5.3	30.93	4,933	159.5	6,056	195.8	6,990	226.0	7,825	253.0	8,557	276.6	9,254	299.2
	3.6	19.24	2,794	145.2	3,429	178.2	3,968	206.2	4,423	229.9	4,857	252.4	5,238	272.2
6.0	4.6	22.72	3,349	147.4	4,111	180.9	4,748	209.0	5,311	233.7	5,811	255.7	6,273	276.1
	3.0	14.13	1,904	134.7	2,331	165.0	2,689	190.3	3,008	212.8	3,303	233.7	3,559	251.9
5.0	3.9	15.78	2,135	135.3	2,612	165.5	3,020	191.4	3,376	213.9	3,697	234.3	3,992	253.0
	2.6	9.86	1,215	123.2	1,486	150.7	1,719	174.3	1,920	194.7	2,099	212.8	2,265	229.9
4.8	3.6	13.76	1,786	129.8	2,195	159.5	2,535	184.2	2,830	205.7	3,103	225.5	3,353	243.6
	2.4	8.52	1,007	118.2	1,237	145.2	1,429	167.7	1,598	187.5	1,748	205.1	1,888	221.6
4.3½	3.2½	11.51	1,431	124.3	1,754	152.3	2,026	176.0	2,266	196.9	2,482	215.6	2,678	232.6
	2.1⅝	7.14	809	113.3	990	138.6	1,143	160.0	1,280	179.3	1,402	196.3	1,512	211.7
4.0	3.0	10.10	1,222	121.0	1,494	147.9	1,728	171.0	1,933	191.4	2,116	209.5	2,289	226.6
	2.0	6.28	691	110.0	846	134.7	974	155.1	1,091	173.8	1,195	190.3	1,292	205.7
3.9	2.9¾	8.87	1,039	117.1	1,268	143.0	1,468	165.5	1,639	184.8	1,795	202.4	1,942	218.9
	1.10½	5.52	589	106.7	723	130.9	832	150.7	932	168.8	1,020	184.8	1.098	199.6
3.4½	2.6¼	7.17	793	110.5	970	135.3	1,120	156.2	1,254	174.9	1,372	191.4	1,483	206.8
	1.8¼	4.47	447	100.1	548	122.6	634	141.9	708	158.4	777	173.8	838	187.5
3.0	2.3	5.68	594	104.5	725	127.6	837	147.4	937	165.0	1,028	180.9	1,109	195.2
	1.6	3.53	336	95.1	412	116.6	476	134.7	532	150.7	582	165.0	629	178.2
2.9	2.0¾	4.77	477	100.1	585	122.6	677	141.9	756	158.4	829	173.8	895	187.5
	1.4½	2.97	271	91.3	332	111.6	384	129.2	430	144.6	470	158.4	508	171.0
2.5½	1.10¼	3.82	361	94.6	443	116.0	511	133.6	571	149.6	626	163.9	677	177.1
	1.2¾	2.37	203	85.8	249	105.0	288	121.5	322	135.8	353	149.0	381	160.6
2.0	1.6	2.52	213	84.7	263	104.5	304	120.4	340	134.7	371	147.4	402	159.5
	1.0	1.57	122	77.5	149	95.1	173	110.0	193	123.2	212	134.7	228	145.2
1.6	1.1½	1.41	104	73.7	127	90.2	147	104.5	164	116.6	180	127.6	195	138.0
	.9	0.88	59	66.5	72	81.9	83	94.6	93	105.6	102	116.0	110	124.8
1.0	.9	0.63	38	59.9	46	73.7	54	85.2	60	95.1	66	104.5	71	112.7
	.6	0.39	22	55.0	26	67.1	30	77.5	34	86.9	37	95.1	40	102.8

EGG-SHAPED CULVERTS.—TABLE 4c.

TABLE OF DISCHARGE AND VELOCITIES,

IN CUBIC AND LINEAL FEET PER MINUTE,

For different sized Culverts or Sewers of the Egg form, *not full*, but carrying Water to the several Depths and Areas specified in each case.

The use of this Table may be extended by the following Rule:—

For the Discharge and Velocity of a Culvert having a fall of (Ft. ℔ Mile.)	Take twice the Discharge & Velocity from the Columns of (Ft. ℔ Mile.)	For the Discharge and Velocity of any Culvert having a fall of (Ft. ℔ Mile.)	Take half the Discharge & Velocity from the Columns of (Ft. ℔ Mile.)
8	2	½	2
12	3	¾	3
16	4	1	4
20	5	1¼	5
24	6	1½	6
28	7	1¾	7

RATE OF FALL.				2 Feet ℔ Mile.		3 Feet ℔ Mile.		4 Feet ℔ Mile.		5 Feet ℔ Mile.		6 Feet ℔ Mile.		7 Feet ℔ Mile.	
Size of Culverts.		Quantity Running. Depth	Area	Dis. per Min.	Vel. per Min.	Dis. per Min.	Vel per Min.	Dis. per Min.	Vel. per Min.	Dis. per Min.	Vel. per Min.	Dis. per Min.	Vel. per Min.	Dis. per Min.	Vel. per Min.
Ft. Ins. Vert.	Ft. Ins. Trans	Ft. In.	Sq.Ft.	C Ft.	Feet.	C.Ft.	Feet.	C.Ft.	Feet.	C.Ft.	Feet.	C.Ft.	Feet.	C.Ft.	Feet.
6 3	×3 9	4 6	13.37	1654	123.7	2029	151.8	2316	173.2	2417	195.8	2867	214.5	3095	231.5
		3 2	8.52	974	114.4	1194	140.2	1382	162.2	1546	181.5	1691	198.5	1827	214.5
5 10	×3 6	4 3	11.75	1402	119.3	1719	146.3	1983	168.8	2215	188.6	2429	206.8	2623	223.3
		2 11	7.14	777	108.9	954	133.6	1103	154.5	1233	172.7	1350	189.2	1460	204.6
5 5	×3 3	4 0	10.37	1197	115.5	1471	141.9	1699	163.9	1899	183.1	2076	200.2	2247	216.7
		2 8¾	6.22	653	105.0	803	129.2	927	149.0	1036	166.6	1135	182.6	1224	196.9
4 7	×2 9	3 5	7.51	805	107.2	987	131.4	1135	151.2	1272	169.4	1391	185.3	1503	200.2
		2 3½	4.48	436	97.3	534	119.3	618	138.0	692	154.5	756	168.8	818	182.6
3 9	×2 3	2 9	4.93	474	96.2	580	117.7	672	136.4	751	152.3	824	167.2	889	180.4
		1 10¾	2.98	255	85.8	313	105.0	362	121.5	404	135.8	442	148.5	478	160.6
3 4	×2 0	2 6	4.01	364	90.7	445	111.1	514	128.1	573	143.0	628	156.7	679	169.4
		1 8	2.37	196	83.0	241	101.7	277	117.1	311	131.4	340	143.5	367	155.1
2 0	×1 3	1 6	1.49	105	70.9	130	87.4	150	100.6	168	112.7	183	123.2	187	133.1
		1 0	0.87	52	59.9	64	73.7	74	85.2	82	95.1	90	103.9	98	112.7
1 4	×0 10	1 0	0.66	38	58.3	47	70.9	54	81.9	61	91.8	66	100.6	72	108.9
		0 8	0.39	20	53.3	25	66.0	29	75.9	33	85.2	36	93.5	39	100.6

PIPES UNDER PRESSURE.—Table 5.

TABLE FOR DISCHARGE,

IN CUBIC FEET PER MINUTE,

APPLICABLE TO ANY LENGTH AND FALL.

Diameter of Pipes 1 inch to 10 feet.

Rule.—When the length, fall, and diameter are given, *divide the tabular number opposite the diameter by the square root of the rate of inclination;* the result will be the discharge in cubic feet per minute.

When the length, fall, and discharge are given, *multiply the discharge by the square root of the rate of inclination; find the nearest corresponding number in the table,* and opposite to it is the required diameter.

When the length, discharge and diameter of pipes are given, *divide the tabular number for the given diameter by the discharge; square the result, and divide by it the length of pipe;* the quotient is the head required for driving the given quantity of water through the pipe.

Note.—All terms are to be taken *in feet* and *cubic feet per minute.*

Diameter of Pipes.		Tabular No.	Diameter of Pipes.		Tabular No.	Diameter of Pipes.		Tabular No.
Ft.	In.	$\div \sqrt{\text{Fall}}$.	Ft.	In.	$\div \sqrt{\text{Fall}}$.	Ft.	In.	$\div \sqrt{\text{Fall}}$.
0	1	4.7	1	9	9,544	3	6	53,994
0	1½	13.0	1	10	10,717	3	7	57,250
0	2	26.4	1	11	4,971	3	8	60,625
0	3	73.6	2	0	13,327	3	9	64,142
0	4	150.7	2	1	14,753	3	10	67,770
0	5	262.9	2	2	16,267	3	11	71,494
0	6	416.5	2	3	17,881	4	0	75,391
0	7	611.4	2	4	19,523	4	3	87,713
0	8	852.8	2	5	21,375	4	6	101,190
0	9	1,147.7	2	6	23,282	4	9	115,844
0	10	1,492.1	2	7	25,263	5	0	131,700
0	11	1,892	2	8	27,335	5	6	167,134
1	0	2,356	2	9	29,545	6	0	207,752
1	1	2,875	2	10	31,826	6	6	253,764
1	2	3,459	2	11	34,208	7	0	305,384
1	3	4,115	3	0	36,726	7	6	362,871
1	4	4,806	3	1	39,319	8	0	426,436
1	5	5,621	3	2	42,018	8	6	496,220
1	6	6,492	3	3	44,861	9	0	572,343
1	7	7,259	3	4	47,674	9	6	655,124
1	8	8,439	3	5	50,811	10	0	745,014

Example.—Required the discharge of a pipe 6 inches diameter and 2,000 feet long, with 20 feet fall:—

$$\frac{2{,}000}{20} = \text{fall 1 in 100, then } \sqrt{100} = 10$$

$$\text{and Tabular Number } \frac{416.5}{10} = 41.65 \text{ cubic feet per minute.}$$

Note.—If half the tabular numbers be taken, the discharge will be nearly that for pipes half full, and the table is thus applicable to sewers, drains, &c.

PIPES UNDER PRESSURE.—Table 5a.

TABLE OF DISCHARGE AND VELOCITIES,

IN CUBIC AND LINEAL FEET PER MINUTE.

FOR PIPES RUNNING FULL WITH A CONSTANT HEAD.

Diameters from 3 to 60 Inches,

With Rates of Fall extending from 5 feet to 35 feet per Mile.

FALL.	5 Feet ℔ Mile.		10 Feet ℔ Mile.		15 Feet ℔ Mile.		20 Feet ℔ Mile.		25 Feet ℔ Mile.		30 Feet ℔ Mile.		35 Feet ℔ Mile.	
RATE.	1 in 1056.		1 in 528.		1 in 352.		1 in 264.		1 in 211.2		1 in 176.0		1 in 150.86	
Diam. of Pipes.	Disch. per Min.	Vel per Min.	Disch. per Min.	Vel. per Min.	Disch. per Min.	Vel. per Min.	Disch. per Min	Vel. per Min.	Disch. per Min.	Vel. per Min.	Disch. per Min.	Vel. per Min.	Disch. per Min.	Vel. per Min
INCHES.	C Feet	Feet.	C Feet	Feet.	C Feet	Feet	C Feet	Feet.	C Feet	Feet.	C Feet	Feet.	C Feet	Feet.
3	2.26	45.3	3.2	64.0	3.9	78.4	4.5	90.4	5.06	101.2	5.55	111.0	6.0	119.8
6	12.8	65.4	18.1	92.4	22.2	113.3	25.6	130.7	28.6	146.1	31.4	160.0	33.9	172.9
9	35.3	79.9	49.9	113.0	61.1	138.3	70.6	159.5	79.0	178.4	86.5	195.6	93.4	211.1
12	72.5	92.5	102.5	130.6	126	159.5	155	196.7	162	205.9	178	225.5	192	243.6
15	127	103.8	179	146.8	219	179.8	253	207.5	283	231.9	310	254.4	335	274.6
18	200	113.5	282	160.3	346	196.5	399	226.8	447	253.7	489	278.0	528	300.4
21	294	122.4	415	173.0	509	211.2	587	244.1	657	273.1	720	299.3	777	323.2
24	410	130.6	580	184.7	710	226.2	820	261.0	917	292.0	1,005	319.7	1,085	345.5
27	550	138.6	778	196.0	953	240.1	1,100	277.1	1,230	309.9	1,348	339.5	1,456	366.5
30	716	146.2	1,013	206.8	1,241	253.1	1,432	292.2	1,602	326.8	1,755	358.1	1,895	386.6
33	909	153.3	1,286	216.8	1,575	265.5	1,817	306.3	2,033	342.7	2,228	375.6	2,405	405.5
36	1,130	160.1	1,598	226.3	1,957	277.3	2,259	319.9	2,527	357.8	2,769	392.2	2,989	423.4
39	1,380	166.5	1,952	235.4	2,391	288.4	2,759	332.8	3,086	372.3	3,383	408.7	3,652	440.4
42	1,661	172.7	2,350	244.2	2,878	299.2	3,321	345.3	3,715	386.3	4,071	423.4	4,395	457.1
45	1,974	178.8	2,791	252.8	3,419	309.7	3,945	357.3	4,413	399.8	4,836	437.2	5,221	473.0
48	2,320	184.7	3,281	261.2	4,018	319.9	4,637	369.1	5,187	412.9	5,684	452.5	6,137	488.5
51	2,699	190.3	3,817	269.2	4,675	329.7	5,394	380.3	6,035	425.5	6,614	466.3	7,140	503.4
54	3,110	195.6	4,403	276.9	5,393	339.2	6,223	391.4	6,959	437.7	7,630	479.9	8,237	518.1
57	3,564	201.1	5,041	284.5	6,174	348.4	7,124	401.9	7,967	449.6	8,735	492.7	9,430	531.9
60	4,052	206.4	5,731	291.9	7,020	357.6	8,100	412.6	9,058	461.4	9,930	505.8	10720	546.1

FRICTION OF BENDS.—Table 6

THEORETIC HEAD IN INCHES

Required to overcome resistance of Bends from 10° to 9

FOR PIPES, CULVERTS, DRAINS, AND RIVERS,

With Currents having the mean velocities stated in the first column

Note.—The numbers give the height in inches or decimals required to drive water past the specified bends, varying according to the velocity of discharge.

Examples.—A pipe carrying water at a mean velocity of 300 feet per minute
has 3 bends of 20 degrees each .126 × 3 = .378
and 7 bends of 50 degrees each .632 × 7 = 4.424
and 20 bends of 40 degrees each .446 × 20 = 8.920

Total head required 13.722 inches.

A River having a mean velocity of 110 feet per minute
has 5 bends of 45 degrees each = .072 × 5 = .360
and 3 bends of 70 degrees each = .128 × 3 = .384
and 2 bends of 90 degrees each = .144 × 2 = .288

Total additional fall required 1.032 inch.

Mean Velocity of Current.	Angles of Bend with forward line of direction.									
	10°	20°	30°	40°	45°	50°	60°	70°	80°	90°
Feet per Minute.	Ins. of Head.	Ins. of Head.	Ins. of Head.	Ins. of Head.	Ins. of Head.	Ins. of Head.	Ins. of Head.	Ins. of Head.	Ins. of Head.	Ins. of Head.
15	.00008	.0003	.0006	.0011	.0013	.0016	.0020	.0024	.0026	.0027
20	.00014	.0005	.0012	.0020	.0024	.0028	.0036	.0042	.0046	.0048
25	.00022	.0009	.0018	.0031	.0037	.0044	.0056	.0066	.0072	.0075
30	.0003	.0012	.0027	.0044	.0054	.0063	.0081	.0095	.0104	.0108
35	.0004	.0017	.0036	.0060	.0073	.0086	.0110	.0129	.0142	.0147
40	.0006	.0022	.0048	.008	.0096	.012	.014	.016	.018	.019
45	.0007	.0028	.0060	.010	.012	.014	.018	.021	.023	.024
50	.0009	.0035	.0075	.012	.015	.017	.022	.026	.029	.030
55	.0011	.004	.009	.015	.018	.021	.027	.032	.035	.036
60	.0013	.005	.011	.018	.021	.025	.032	.038	.042	.043
65	.0015	.006	.012	.021	.025	.029	.037	.045	.049	.050
70	.0017	.007	.015	.024	.029	.034	.044	.052	.057	.059
75	.0020	.008	.017	.028	.033	.039	.050	.060	.065	.067
80	.0023	.009	.019	.031	.038	.042	.057	.068	.074	.077
85	.0026	.010	.022	.036	.043	.051	.064	.076	.084	.087
90	.0029	.011	.024	.040	.048	.057	.072	.086	.094	.097
95	.0032	.012	.027	.045	.054	.063	.081	.095	.105	.108
100	.0036	.014	.030	.049	.060	.070	.090	.106	.116	.120
105	.0039	.015	.033	.054	.066	.077	.099	.117	.128	.134
110	.0043	.017	.036	.060	.072	.085	.108	.128	.140	.144
120	.0052	.020	.043	.071	.086	.101	.129	.152	.167	.173
130	.0061	.023	.050	.083	.101	.119	.151	.179	.196	.202
140	.0070	.027	.059	.097	.117	.138	.176	.207	.228	.235
150	.0081	.031	.067	.111	.135	.158	.202	.238	.261	.270
175	.0111	.043	.092	.153	.185	.217	.277	.327	.357	.370
200	.014	.056	.120	.198	.240	.281	.360	.424	.405	.480
250	.022	.087	.187	.309	.375	.439	.562	.662	.726	.750
300	.032	.126	.270	.446	.540	.632	.810	.953	1.046	1.080
350	.044	.172	.367	.607	.735	.867	1.102	1.298	1.424	1.470
400	.057	.224	.480	.793	.960	1.125	1.440	1.695	1.860	1.920

TABLE OF APPROXIMATE RISE OF WATER,

[...]CASIONED BY BRIDGES, WEIRS, &c.,

From Gregory's "Mathematics for Practical Men."

[...]—This table is approximative only, because the velocity must be an ever varying quantity, fluctuating at all times with the amount of river flood, and also greatly depending on the state of river section above and below bridge. The table was taken by Dr. Olinthus Gregory, from Du Buat's theorems.

Vel. of Stream	Probable Rise of Water, For Obstructions from one-tenth to six-tenths; the whole section of the River being taken as unity. OBSTRUCTION.					
	.10	.20	.30	.40	.50	.60
Feet per Min.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
180	.05	.12	.21	.36	.61	1.07
240	.08	.18	.34	.58	.97	1.70
300	.12	.28	.52	.88	1.49	2.60
360	.16	.37	.69	1.18	1.99	3.49
480	.27	.64	1.19	2.03	3.42	5.99
600	.42	.99	1.83	3.12	5.27	9.22

SMEATON'S TABLE OF THE HEAD

FOR DRIVING WATER THROUGH 100 FEET LINEAL OF PIPES,

From 1 to 12 inches diameter, at Velocities increasing from 90 to 270 feet per minute, with the relative discharge in cubic feet per minute, compiled from Smeaton's Papers.

Diam of Pipes	Assumed Velocities of Water through Pipes in Feet per Minute. 90		120		150		180		210		240		270	
	Dis	Head.	Dis.	Head.	Dis.	Head	Dis.	Head.	Dis.	Head	Dis.	Head.	Dis.	Head.
Inches.	C. Ft. per M.	Feet.	C. Ft. per M.	Feet.	C. Ft. per M	Feet.	C. Ft per M.	Feet.	C. Ft per M.	Feet.	C Ft. per M	Feet	C Ft. per M.	Feet.
1	.45	1.46	.60	2.40	.76	3.58	.92	5.04	1.08	6.83	1.23	8.92	1.39	11.30
1.5	1.01	0.97	1.36	1.60	1.69	2.38	2.03	3.36	2.36	4.56	2.92	5.94	3.05	7.52
2	1.81	0.74	2.41	1.20	3.01	1.80	3.62	2.52	4.22	3.42	4.82	4.46	5.43	5.63
3	4.41	0.42	5.88	0.80	7.35	1.20	8.82	1.68	10.3	2.28	11.7	2.97	13.2	3.76
4	7.69	0.37	10.26	0.60	12.82	0.90	15.39	1.26	17.9	1.72	20.5	2.23	23.1	2.81
6	17.7	0.24	23.5	0.40	29.4	0.60	35.2	0.84	41.2	1.14	47.0	1.48	53.0	1.87
9	39.8	0.156	53.04	0.27	66.3	0.40	79.6	0.56	92.8	0.76	106	0.99	119	1.25
12	70.7	0.12	94.2	0.20	118	0.31	141	0.42	165	0.57	188	0.74	212	0.94

This Table will be found to be somewhat similar in its results to Table 5, but is not of so extensive an application, and gives too low a discharge on the larger class of pipes.

Example.—.42 feet is the head per 100 feet to drive 141 cubic feet, at a velocity of 180 feet per minute, through a 12-inch pipe.

MOTION AND RESISTANCE OF WATER.—TABLE 6b.

TABLE OF THE RESISTANCE TO ONE SQUARE FOOT,

Moving through Water (or vice versâ),

At Velocities from 60 to 900 Feet per Minute,

And at angles with the line of force from 6 to 90 Degrees.

Note.—This table gives the *theoretical* resistance due to the several velocities, and is computed by the formula $.975 \times \sqrt{\text{vel. in feet per second}}$ = resistance at right angles per square foot, in lbs. The angular resistances are computed from the same formula as Hutton's Experiments, as explained at the head of Table 6c. Resistance for variable figures appears to be almost beyond any assigned rule; for the best information see Beaufoy's Experiments. Resistance under circumstances of compound motion should be at its maximum, according to the known effects of water-wheels, when the surface moves at from one-half to two-thirds of the velocity of the fluid, when the best applications produce 75 per cent. of the weight; although at high velocities only 30 per cent. is produced.

Angle of Surface, with Line of Resistance.	Pressure per Square Foot for the following Velocities per Minute.							
	60 Feet.	120 Feet.	180 Feet.	240 Feet.	300 Feet.	480 Feet.	600 Feet.	900 Feet.
Degrees	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
6	.022	.090	.202	.359	.561	1.435	2.242	5.046
7	.027	.109	.246	.437	.682	1.747	2.730	6.142
8	.033	.133	.298	.530	.829	2.122	3.315	7.459
9	.039	.156	.351	.624	.975	2.496	3.900	8.775
10	.045	.179	.404	.718	1.121	2.870	4.485	10.091
15	.089	.355	.798	1.420	2.218	5.678	8.872	19.963
20	.152	.608	1.369	2.434	3.802	9.734	15.210	34.222
25	.235	.940	2.115	3.760	5.874	15.038	23.497	52.869
30	.338	1.353	3.045	5.413	8.458	21.653	33.832	76.123
35	.449	1.798	4.045	7.192	11.237	28.766	44.947	101.132
40	.565	2.258	5.081	9.032	14.113	36.130	56.452	127.018
45	.665	2.660	5.985	10.639	16.624	42.557	66.495	149.614
50	.749	2.995	6.739	11.981	18.720	47.923	74.880	168.480
55	.812	3.249	7.310	12.995	20.304	51.979	81.217	182.739
60	.864	3.455	7.775	13.822	21.596	55.286	86.385	194.366
65	.902	3.607	8.117	14.430	22.547	57.720	90.187	202.922
70	.932	3.728	8.389	14.914	23.302	59.654	93.210	209.722
75	.953	3.810	8.573	15.241	23.814	60.965	95.257	214.329
80	.966	3.857	8.678	15.428	24.107	61.714	96.427	216.926
85	.973	3.892	8.757	15.569	24.326	62.275	97.305	218.936
90	**.975**	**3.900**	**8.775**	**15.600**	**24.375**	**62.400**	**97.500**	**219.375**

TABLE OF THE RESISTANCE TO ONE SQUARE FOOT,

Moving through Air (or vice versâ),

At Velocities from 720 to 3,600 Feet per Minute,

And at angles with the line of force from 6 Degrees to 90 Degrees, or Right Angles.

From Hutton's Experiments.

Note.—Dr. Hutton found that the resistance varied as the square of the velocity nearly, and to an inclined surface, as the 1.84 power of the sine × cosine. This table is constructed thus:—.841 s 1.84 c = resistance in ounces to a plate 32 square inches, moving at the rate of 12 feet per second. Mr. Hutton's experiments went to show that the figure of a plane makes no sensible difference in the resistance, but that a convex surface of a hemisphere with a surface double the base, had only half the resistance, and a cone with 74 inches area, at an angle of 25.42, suffers far less resistance than a plane of equal angle, with 32 inches area; the areas being as 74 to 32, and the resistance as 37 to 25. It must be observed that at high velocities, railway and fast canal boat experiments shew that resistance becomes nearly a constant quantity.

Angle of Surface, with Line of Resistance.	Pressure per Square Foot for the following Velocities per Minute.						
	720 Feet.	1,080 Feet.	1,440 Feet.	1,800 Feet.	2,400 Feet.	3,000 Feet.	3,600 Feet.
Degrees	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs
6	.0054	.0121	.0216	.0337	.060	.094	135
7	.0066	.0148	.0264	.0412	.074	.115	.165
8	.0080	.0180	.0320	.0500	.089	.139	.200
9	.0094	.0211	.0376	.0587	.105	.163	.235
10	.0109	.0245	.0436	.0680	.121	.189	.272
15	.0215	.0484	.0860	.1344	.239	.373	.537
20	.0368	.0828	.1472	.2300	.409	.639	.920
25	.0569	.1280	.2276	.3556	.632	.988	1.422
30	.0820	.1845	.3280	.5325	.911	1.423	2.050
35	.1089	.2450	.4356	.6806	1.210	1.890	2.722
40	.1368	.3078	.5472	.8550	1.520	2.375	3.420
45	.1611	.3625	.6444	1.0069	1.790	2.797	4.027
50	.1814	.4081	.7256	1.1337	2.015	3.149	4.535
55	.1968	.4428	.7872	1.2300	2.186	3.416	4.920
60	.2093	.4709	.8372	1.3081	2.325	3.633	5.232
65	.2185	.4916	.8740	1.3656	2.427	3.793	5.462
70	.2258	.5080	.9032	1.4112	2.509	3.920	5.645
75	.2308	.5193	.9232	1.4415	2.564	4.007	5.770
80	.2336	.5256	.9344	1.4600	2.596	4.055	5.840
85	.2358	.5305	.9432	1.4737	2.620	4.093	5.895
90	**.2362**	**.5314**	**.9448**	**1.4762**	**2.624**	**4.100**	**5.905**

VALUE OF WATER POWER.—Table 7

TABLE OF NOMINAL HORSE POWER,

FOR ONE FOOT OF FALL,

With the different Effective Values as applied to Undershot Breast and Overshot Wheels and to the Turbine.

Rule.—Add together the numbers, from the column applicable to the case, opposite the several amounts of cubic feet making up the estimated run of the streams, and multiply the sums by the number of feet of fall; the result is the H. power of the Mill.

Note.—An ordinary Mill will grind about 1 bushel per horse power per hour—a very good one 1.2 bushels—therefore multiply the tabular numbers by 1 or 1.2 (according to the case), and by the number of hours worked, for the bushels ground per diem.

Discharge of Stream per Minute.	Nominal Horse Power.	Undershot Wheel.	Breast Wheel.	Overshot Wheel.	Turbine.
		Effective H. Power.	Effective H. Power.	Effective H. Power.	Effective H. Power.
Cubic Feet.					
5	.0095	.0033	.0052	.00615	.0071
10	.019	.0066	.016	.012	.0142
15	.028	.0099	.015	.018	.021
20	.038	.013	.020	.024	.028
25	.048	.016	.026	.031	.035
30	.057	.020	.031	.037	.042
35	.066	.023	.036	.043	.050
40	.076	.026	.041	.049	.057
45	.085	.030	.046	.055	.064
50	**.095**	**.033**	**.052**	**.061**	**.071**
55	.104	.036	.057	.068	.078
60	.114	.040	.062	.074	.085
65	.124	.043	.c67	.080	.092
70	.133	.046	.072	.086	.099
75	.142	.050	.078	.092	.106
80	.152	.053	.083	.098	.113
85	.161	.056	.088	.104	.121
90	.171	.059	.093	.111	.128
95	.180	.063	.098	.117	.135
100	**.190**	**.066**	**.104**	**.123**	**.142**
200	.380	..130	.208	.246	.284
300	.570	.200	.312	.369	.426
400	.760	.260	.416	.492	.568
500	.950	.330	.520	.615	.710
600	1.140	.400	.624	.738	.852
700	1.330	.460	.728	.861	.994
800	1.520	.530	.832	.984	1.136
900	1.710	.590	.936	1.107	1,278
1,000	**1.900**	**.660**	**1.040**	**1.230**	**1.420**
2,000	3.800	1.300	2.080	2.460	2.846
3,000	5.700	2.000	3.120	3.690	4.260
4,000	7.600	2.600	4.160	4.920	5.680
5,000	9.500	3.300	5.200	6.150	7.100
6,000	11.400	4.000	6.240	7.380	8.520
7,000	13.300	4.600	7.280	8.610	9.940
8,000	15.200	5.300	8.320	9.840	11.360
9,000	17.100	5.950	9.360	11.070	12.780
10,000	**19.000**	**6.600**	**10.400**	**12.300**	**14.200**

VALUE OF STEAM POWER.—Table 8

PROPORTIONS OF DOUBLE-ACTING STEAM ENGINES,

Expansive and Non-expansive,

WITH THE WATER EVAPORATED AND COALS CONSUMED.

Note.—*For Condensation allow* 30 *Cubic Feet of Water for every Cubic Foot evaporated.*

Total Water required for Supply of an Engine = .41 Cubic Feet per Minute per Horse-Power.

Steam Acting Expansively. Mean pressure being 6.1 lbs. per square inch through the Stroke.							Steam acting at full pressure throughout the stroke, or 9lb. per square inch.	
Horse Power.	Diameter of Piston.	Velocity of Piston per minute.	Length of Stroke.	Strokes per minute.	Water evaporated per hour.	Coals consumed per hour.	Horse Power.	Coals consumed per hour.
	inches.	feet.	feet.	number.	cubic feet.	lbs.		lbs.
1	7.8	114	1.3	44	0.8	15	1.46	31.5
2	10.25	131	1.75	37½	1.57	23	2.95	48
3	12.05	141	2.	35	2.36	30	4.4	64
4	13.52	149	2.25	33	3.13	38	5.9	80
5	14.9	157	2.5	31½	3.92	45	7.4	94
6	15.9	162	2.65	30½	4.7	53	8.85	111
7	16.9	167	2.8	29¾	5.5	60	10.3	126
8	17.85	171	2.97	29	6.3	67	11.8	140
9	18.7	175	3.1	28¼	7.05	73	13.3	153
10	19.5	180	3.25	26¾	7.82	80	14.6	168
12	20.9	186	3.5	26½	9.4	95	17.7	199
14	22.3	191	3.7	25¾	11.0	109	20.7	230
16	23.6	196	3.9	25	12.6	122	23.6	256
18	24.7	201	4.1	24½	14.1	135	26.5	283
20	25.75	206	4.3	24	15.7	149	29.5	312
24	27.7	213	4.6	23½	18.8	176	35.5	370
28	29.45	220	4.9	22½	22.0	203	41.3	425
30	30.27	222	5.04	22¼	23.5	216	44.2	451
34	31.82	229	5.3	21½	26.7	243	50.	510
38	33.3	234	5.55	21	29.7	269	56.	561
40	34.0	237	5.67	21	31.4	283	59.	596
44	35.13	241	5.85	20½	34.5	311	65.	652
48	36.5	246	6.1	20¼	37.7	338	70.5	709
50	37.13	248	6.2	20	39.3	353	73.5	739
54	38.3	252	6.4	19¾	42.4	381	79.3	798
58	39.4	255	6.57	19½	45.4	409	85.1	856
60	39.9	257	6.65	19¼	47.0	423	88.1	887
64	41.0	260	6.83	19	50.2	452	93.9	946
68	42.0	263	7.0	18¾	53.4	481	99.7	1005
70	42.5	265	7.1	18¾	55.0	495	102.7	1035
74	43.4	268	7.23	18½	58.1	514	108.5	1094
78	44.4	270	7.4	18¼	61.5	554	114.3	1153
80	44.8	272	7.47	18¼	62.5	563	117.3	1182
85	45.9	275	7.65	18	66.5	599	124.6	1256
90	46.97	279	7.83	17¾	70.5	635	131.9	1330
95	48.0	282	8.0	17¾	74.4	670	139.2	1404
100	49.0	284	8.16	17½	78.2	704	146.0	1478
110	50.9	290	8.5	17	86.0	774	161.6	1626
120	52.7	294	8.8	16¾	93.8	844	175.2	1774
130	54.4	299	9.0	16½	101.7	915	189.8	1921
140	56.1	302	9.35	16¼	109.5	986	204.4	2069
150	57.6	308	9.6	16	117.3	1055	219.0	2217
160	59.1	312	9.83	15¾	125.2	1127	233.6	2364
180	62.0	320	10.3	15½	133.0	1197	248.4	2512
200	67.7	334	11.3	14¾	156.4	1408	292.0	2956

EQUIVALENT COLUMNS OF MERCURY & WATER;

With their Pressure per square inch and per square foot.

Applicable to Steam Gauges and Pressure Gauges, for Pumping Engines, and for calculating the strength of Pipes, Tanks, &c., &c.

Column of Mercury.	Equivalent of Water.	Pressure per sq.inch.	Pressure per sq.foot.	Column of Mercury.	Equivalent of Water.	Pressure per sq.inch	Pressure per sq.foot.
Inches.	Feet.	lbs.	lbs.	Inches.	Feet.	lbs.	lbs.
.1	.113	.049	7.07	28.56	32.39	**14.00**	2016
.2	.226	.098	14.14	29.00	32.88	14.21	2050
.3	.339	.147	21.21	30.00	33.92	14.70	2121
.4	.452	.196	28.28	30.60	34.71	**15.00**	2160
.5	.565	.245	35.35	31.00	35.05	15.19	2191
.6	.678	.294	42.42	32.00	36.18	15.68	2262
.7	.791	.343	49.49	32.64	37.02	**16.00**	2304
.8	.904	.392	56.56	33.00	37.31	16.17	2333
.9	1.017	.441	63.63	34.00	38.44	16.68	2404
1.0	**1.1306**	**.490**	**70.70**	**34.68**	**39.33**	**17.00**	**2448**
2.0	2.260	.980	141.	35.00	39.57	17.15	2474
2.04	2.314	**1.00**	144	36.00	40.70	17.64	2545
3.0	3 39	1.47	212	36.72	41.62	**18.00**	2592
4.0	4.52	1.96	282	37.00	41.83	18.13	2616
4.08	4.63	**2.00**	288	38.00	42.96	18.62	2686
5.	5.65	2.45	353	38.76	43.96	**19.00**	2736
6.	6.78	2.94	424	39.00	44.09	19.11	2757
6.12	6.94	**3.00**	432	40.00	45.22	19.60	2828
7.	7.91	3.43	495	40.80	46.28	**20.00**	2880
8.	**9.04**	**3.92**	**565**	**42.84**	**48.59**	**21.00**	**3024**
8.16	9.25	**4.00**	576	44.88	50.90	**22.00**	3168
9.	10.17	4.41	636	45.00	50.87	22.05	3181
10.	11.306	4.90	707	46.92	53.21	**23.00**	3312
10.20	11.57	**5.00**	720	48.96	55.52	**24.00**	3456
11.	12.43	5.39	790	50.00	56.53	24.50	3535
12.	13.56	5.88	848	51.00	57.83	**25.00**	3600
12.24	13.88	**6.00**	864	60.00	67.83	29.40	4242
13.	14.69	6.37	919	70.00	79.14	34.30	4949
14.	15.83	6.87	990	80.00	90.44	39.20	5656
14.28	**16.20**	**7.00**	**1,008**	**90.00**	**101.75**	**44.10**	**6363**
15.	16.96	7.36	1,060	100.00	113.06	49.00	7070
16.	18.09	7.85	1,130	110.	124.34	53.90	7777
16.32	18.51	**8.00**	1,152	120.	135.67	58.80	8484
17.	19.22	8.34	1,202	130.	146.70	63.70	9194
18.	20.35	8.83	1,272	140.00	158.	68.70	9898
18.36	20.82	**9.00**	1,296	150.5	170.	73.78	10625
19.	21.48	9.32	1,343	159.3	180.	78.12	11249
20.	22.61	9.81	1,414	168.2	190.	82.46	11874
20.40	23.14	**10.00**	1,440	177.	200.	86,80	12499
21.	**23.74**	10.29	**1,484**	**194.7**	**220.**	**95.48**	**13749**
22.	24.87	10.78	1,555	212.3	240.	104.16	14999
22.44	25.45	**11.00**	1,584	221.3	250.	108.50	15624
23.0	26.00	11.27	1,626	230.1	260.	112.80	16243
24.	27.13	11.76	1,696	247.8	280.	121.50	17496
24.48	27.76	**12.06**	1,728	265.3	300.	130.20	18748
25.00	28.26	12.25	1,767	283.06	320.	138.80	19987
26.	29.39	12.74	1,838		350.	151.90	21873
26.52	30.08	**13.00**	1,872		400.	173.60	24998
27.	30.52	13.23	1,909		450.	195.30	28123
28.	**31.65**	**13.72**	**1979**		**500.**	**217.00**	**31248**

WEIGHT AND STRENGTH OF PIPES—TABLE 10

WEIGHT PER YARD AND SAFE HEAD OF WATER FOR CAST-IRON PIPES.

Diameters 3 to 48 inches.

NOTE.—The *weight* includes a proportion for socket at every 9 feet, allowing the clear length of each pipe when laid to make 3 yards, thus each pipe would be about 9 feet 6 inches from out to out. The *safe head* is that to which the pipes may be constantly exposed. The proof head may be double the tabular amount if the circumstances require.

Bore.	Thickness.	Weight.			Safe Head of Water.	Bore.	Thickness.	Weight.			Safe Head of Water.
inches.	inches.	cwts.	qrs.	lbs.	feet.	inches.	inches.	cwts.	qrs.	lbs.	feet.
3	1/4	0	1	0	1000	**14**	5/8	2	2	17	535
	3/8	0	1	14	1500		3/4	3	0	18	642
	1/2	0	2	0	2000		7/8	3	2	19	750
	5/8	0	2	14	2500		1	4	0	21	857
4	1/4	0	1	9	744	**15**	5/8	2	3	8	500
	3/8	0	1	25	1128		3/4	3	1	12	600
	1/2	0	2	15	1500		7/8	3	3	19	700
	5/8	0	3	5	1872		1	4	1	23	800
5	1/4	0	1	18	600	**16**	5/8	3	0	0	468
	3/8	0	2	11	900		3/4	3	2	9	565
	1/2	0	3	4	1200		7/8	4	0	18	652
	5/8	1	0	0	1500		1	4	3	0	750
6	3/8	0	2	22	750	**18**	5/8	3	1	12	412
	1/2	0	3	2	1000		3/4	4	0	0	500
	5/8	1	0	18	1250		7/8	4	2	16	583
	3/4	1	1	18	1500		1	5	0	23	666
7	3/8	0	3	8	640	**21**	5/8	3	3	18	360
	1/2	1	0	9	857		3/4	4	2	15	428
	5/8	1	1	10	1068		7/8	5	1	15	500
	3/4	1	2	14	1284		1	6	1	14	572
8	3/8	0	3	20	564	**24**	5/8	4	1	19	312
	1/2	1	0	25	750		3/4	5	1	0	374
	5/8	1	2	3	936		7/8	6	1	0	400
	3/4	1	3	9	1128		1	7	0	13	500
9	3/8	1	0	4	500	**30**	3/4	6	3	14	300
	1/2	1	1	12	666		1	8	3	24	400
	5/8	1	2	20	832		1 1/8	9	1	16	450
	3/4	2	0	4	1000		1 1/4	11	0	7	500
10	3/8	1	0	16	450	**36**	3/4	8	0	23	249
	1/2	1	2	0	600		1	10	2	21	333
	5/8	1	3	12	750		1 1/8	11	2	11	375
	3/4	2	1	8	900		1 1/4	13	0	20	412
11	1/2	1	2	15	525	**42**	3/4	9	3	0	216
	5/8	2	0	4	684		1	12	2	12	288
	3/4	2	1	21	816		1 1/8	14	0	7	312
	7/8	2	3	12	960		1 1/4	15	2	0	360
12	1/2	1	3	3	500	**48**	3/4	11	0	14	187
	5/8	2	0	23	625		1	14	1	17	250
	3/4	2	2	17	750		1 1/8	16	0	3	280
	7/8	3	0	12	875		1 1/4	17	0	0	312

FLOOD DISCHARGES.—TABLE 11

DISCHARGE,

IN CUBIC FEET PER MINUTE,

For 1 to 100 Acres, with the following amounts of Rain-fall in 24 hours.

Rain in 24 Hours.	In. 1–32	In. 1–16	In. 1–8	In. 1–4	In. 1–2	In. 3–4	In. 1	Ins. 2	Ins. 3	Ins. 4
Acres.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per min.
1	.078771	.15754	.31508	.63016	1.26	1.8903	2.52	5.0413	7.5620	10.082
2	.157	.31	.6301	1.26	2.52	3.781	5.04	10.08	15.12	20.1
3	.236	.47	.9452	1.89	3.78	5.671	7.56	15.12	22.68	30.2
4	.315	.63	1.260	2.52	5.04	7.562	10.08	20.16	30.25	40.3
5	.394	.78	1.575	3.15	6.30	9.452	12.60	25.20	37.81	50.4
6	.472	.94	1.890	3.78	7.56	11.34	15.12	30.25	45.37	60.5
7	.551	1.10	2.205	4.41	8.82	13.23	17.64	35.29	52.93	70.6
8	.630	1.26	2.520	5.04	10.08	15.12	20.16	40.33	60.49	80.6
9	.709	1.42	2.835	5.67	11.34	17.01	22.68	45.37	68.06	90.7
10	.788	1.57	3.151	6.30	12.60	18.90	25.20	50.41	75.62	100.8
20	1.575	3.15	6.301	12.60	25.20	37.81	50.41	100.8	151.2	201.6
30	2.363	4.72	9.452	18.90	37.81	56.71	75.62	151.2	226.8	302.5
40	3.150	6.30	12.60	25.20	50.41	75.62	100.8	201.6	302.5	403.3
50	3.938	7.87	15.75	31.51	63.01	94.52	126.0	252.0	378.1	504.1
60	4.726	9.45	18.90	37.81	75.62	113.4	151.2	302.5	453.7	604.9
70	5.514	11.03	22.05	44.10	88.22	132.3	176.4	352.9	529 3	705.8
80	6.301	12.60	25.20	50.41	100.8	151.2	201.6	403.3	604.9	806.6
90	7.090	14.18	28.35	56.71	113.4	170.1	226.8	453.7	680.6	907.4
100	7.877	15.75	31.51	63.01	126.0	189.0	252.0	504.1	756.2	1008.2

For 1 to 10 Square Miles, with the following amounts of Rain-fall in 24 hours.

Rain in 24 Hours.	In. 1–32	In. 1–16	In. 1–8	In. 1–4	In. 3–8	In. 1–2	In. 5–8	In. 3–4	In. 7–8	In. 1
Square Miles.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per m.	Cub. ft. per min.
1	50.413	100.82	201.64	403.3	604.96	806.65	1008.26	1209.92	1411.57	1613.23
2	100.8	201.6	403.3	806.6	1209.9	1613.2	2016.5	2419.8	2823.1	3226.4
3	151.2	302.5	604.9	1209.9	1814.9	2419.8	3024.8	3629.7	4234.7	4839.6
4	201.6	403.3	806.6	1613.2	2419.8	3226.4	4033.1	4839.7	5646.3	6452.9
5	252.0	504.1	1008.2	2016.5	3024.7	4033.0	5041.3	6049.6	7057.8	8066.1
6	302.5	604.9	1209.9	2419.8	3629.7	4839.6	6049.6	7259.4	8469.4	9679.3
7	352.9	705.8	1411.5	2823.1	4234.7	5646.3	7057.8	8469.4	9881.0	11292.6
8	403.3	806.6	1613.2	3226.4	4839.7	6452.9	8066.1	9679.3	11292.6	12905.8
9	453.7	907.4	1814.9	3629.7	5444.7	7259.4	9074.4	10889.3	12704.1	14519.0
10	504.1	1008.2	2016.4	4033.0	6049.6	8066.5	10082.6	12099.2	14115.7	16132.3

MEAN DISCHARGE OF ANNUAL RAIN.—TABLE 12

DISCHARGES DUE TO RAINFALL

IN DEPTH FROM TWO TO SIXTY INCHES PER ANNUM.

Rain per Annum.	Cubic feet per minute.		Cubic feet per Diem.		Gallons per Diem.	
Inches.	For 1 acre.	For 1 square mile.	For 1 acre.	For 1 square mile.	For 1 acre.	For 1 square mile.
2	.013802	8.83	19.87	12,720	123.8	79,245
4	.027604	17.66	39.75	25,440	257.6	158,491
6	.041406	26.50	59.62	38,160	371.4	237,736
8	.055208	35.33	79.50	50,880	495.2	316,982
10	.069011	44.16	99.37	63,600	619.0	396,228
12	.082813	53.00	119.25	76,320	742.9	475,473
14	.096614	61.83	139.12	89,040	866.6	554,718
16	.110416	70.66	159.00	101,760	990.5	633,964
18	.124219	79,50	178.87	114,480	1114.2	713,210
20	.138022	88.33	198.74	127,200	1238.0	792,456
22	.151824	97.16	218.62	139,920	1362.0	871,701
24	.165626	106.00	238.50	152,640	1485.8	950,947
26	.179427	114.83	258.37	165,360	1609.5	1030,193
28	.193228	123.66	278.24	178,080	1733.2	1109,438
30	.207033	132.50	298.12	190,800	1857.0	1188,684
33	.2277	145.73	327.90	209,851	2042.8	1307,372
36	.248438	159.00	357.75	228,960	2228.7	1426,420
42	.289842	185.50	417.37	267,140	2599.8	1109,437
48	.331252	212.00	477.00	305,280	2971.6	1901,894
54	.372657	238.50	536.62	343,440	3342.6	2139,630
60	.414066	265.00	596.25	381,600	3714.0	2377,368

SUBSOIL DRAINS.—Table C.

LENGTH OF DRAIN PIPES REQUIRED IN ONE ACRE.

No. of feet apart.	Length in feet.	Length in Rods of 16½ feet.
5	8,702	527.3
6	7,262	440.1
8	5,445	330.1
10	4,350	263.6
12	3,631	220.0
15	2,900	175.7
16½	2,640	160.0
18	2,421	146.7
21	2,073	125.6
24	1,815	110.0
27	1,614	97.8
30	1,450	87.8
33	1,314	80.0
36	1,210	73.3

EXPENDITURE OF WATER.—Table 13

DISCHARGE FOR MINUTES, DAYS AND YEARS, IN CUBIC FEET AND IMPERIAL GALLONS.

Per Minute.		Per Diem.		Per Annum.
Cubic Feet.	Gallons.	Cubic Feet.	Gallons.	Cubic Feet. Millions.
1	6.23	1,440	8,971	.526
2	12.46	2,880	17,948	1.052
3	18.69	4,320	26,922	1.578
4	24.92	5,760	35,896	2.104
5	31.16	7,200	44,870	2.630
6	37.39	8,640	53,844	3.156
7	43.62	10,080	62,818	3.682
8	49.85	11,520	71,792	4.208
9	56.08	12,960	80,766	4.734
10	**62.32**	**14,400**	**89,740**	**5.260**
20	124.64	28,800	179,480	10.520
25	155.80	36,000	224,350	13.150
30	186.96	43,200	269,220	15.780
35	218.12	50,400	314,090	18.410
40	249.28	57,600	358,960	21.040
45	280.44	64,800	403,830	23.670
50	311.60	72,000	448,700	26.300
55	342.76	79,200	493,570	28.930
60	373.92	86,400	538,440	31.560
65	**405.08**	**93,600**	**583,310**	**34.190**
70	436.24	100,800	628,180	36.820
75	467.40	108,000	673,050	39.450
80	498.56	115,200	717,920	42.080
85	529.72	122,400	762,790	44.710
90	560.89	129,600	807,660	47.340
95	592.05	136,800	852,530	49.970
100	623.21	144,000	897,408	52.600
200	1,246.4	288,000	1,794,816	105.200
300	1,869.6	432,000	2,692,224	157.800
400	**2,492.8**	**576,000**	**3,589,632**	**210,400**
500	3,116.1	720,000	4,487,040	263.000
600	3,739.2	864,000	5,384,448	315.600
700	4,362.4	1,088,000	6,281,856	368.200
800	4,985.6	1,152,000	7,179,264	420.800
900	5,608.9	1,296,000	8,076,672	473.400
1,000	6,232.1	1,440,000	8,974,080	526.000
2,000	12,464.0	2,880,000	17,948,160	1,052.000
3,000	18,696.0	4,320,000	26,922,240	1,578.000
4,000	24,928.0	5,760,000	35,896,320	2,104.000
5,000	**31,160.0**	**7,200,000**	**44,870,400**	**2,630.000**
6,000	37,392.0	8,640,000	53,844,480	3,156.000
7,000	43,625.	10,080,000	62,818,560	3,682.000
8,000	49,857.	11,520,000	71,792,640	4,208.000
9,000	56,089.	12,960,000	80,766,720	4,734.000
10,000	62,322.	14,400,000	89,740,800	5,260.000
11,000	68,554.	15,840,000	98,714,880	5,786.000
12,000	74,786.	17,280,000	107,688,960	6,312.000

WATER SUPPLY AND POPULATION.—TABLE 14

WATER SUPPLY AND DRAINAGE AREAS

Required for various amounts of Population, at different rates of Supply, with a Guide to the Cubic Contents of Reservoirs, where that method of Supply is adopted.

Discharge required.		Number of Population.			Gathering Ground required.		Reservoir required.
Cubic Feet per Minute.	Gallons per Diem.	At 30 Gallons per Head, per Diem.	At 40 Gallons per Head, per Diem.	At 50 Gallons per Head, per Diem.	With Stream delivering 8 cubic feet per sq. mile.	With 12 in. of Rain per ann. or 53 c. feet per minute, per sq. mile.	Holding Water for 4 months, at 53 c. feet per min.
Cubic Feet.	Millions.	Number.	Number.	Number.	Square Miles.	Square Miles.	Cubic Feet. Millions.
27.8	.25	8,333	6,250	5,000	3.48	.52	4.88
55.7	.50	16,666	12,500	10,000	6.96	1.05	9.76
83.5	.75	25,000	18,750	15,000	10.44	1.57	14.65
111.4	1.00	33,333	25,000	20,000	13.93	2.10	19.53
139.2	1.25	41,666	31,250	25,000	17.41	2.63	24.42
167.1	1.50	50,000	37,500	30,000	20.89	3.15	29.30
195.0	**1.75**	**58,333**	**43,750**	**35,000**	**24.37**	**3.68**	**34.18**
222.8	2.00	66,666	50,000	40,000	27.85	4.21	39.07
250.7	2.25	75,000	56,250	45,000	31.33	4.73	43.95
278.5	2.50	83,333	62,500	50,000	34.82	5.26	48.84
334.3	3.00	100,000	75,000	60,000	41.78	6.31	58.60
390.0	3.50	116,666	87,500	70,000	48.75	7.36	68.37
445.7	4.00	133,333	100,000	80,000	55.71	8.41	78.14
557.1	**5.00**	**166,666**	**125,000**	**100,000**	**69.64**	**10.52**	**97.68**
668.6	6.00	200,000	150,000	120,000	83.57	12.62	117.21
780.0	7.00	233,333	175,000	140,000	97.50	14.74	136.75
891.4	8.00	266,666	200,000	160,000	111.43	16.82	156.28
1,002.8	9.00	300,000	225,000	180,000	123.11	18.92	175.82
1,114.3	10.00	333,333	250,000	200,000	139.29	21.02	195.36
2,228.6	20.00	666,666	500,000	400,000	278.58	42.05	390.72
3,343.0	**30.00**	**1,000,000**	**750,000**	**600,000**	**417.87**	**63.07**	**586.08**
4,457.3	40.00	1,333,333	1,000,000	800,000	557.16	84.10	781.44
5,571.6	50.00	1,666,666	1,250,000	1,000,000	696.45	105.13	976.80
6,686.0	60.00	2,000,000	1,500,000	1,200,000	835.74	126.15	1,171.16
7,800.3	70.00	2,333,333	1,750,000	1,400,000	975.04	147.18	1,367.52
8,914.6	80.00	2,666,666	2,000,000	1,600,000	1,114.33	168.21	1,562.88
10,029.0	90.00	3,000,000	2,250,000	1,800,000	1,253.62	189.23	1,758.24
11,143.3	**100.00**	**3,333,333**	**2,500,000**	**2,000,000**	**1,392.91**	**210.25**	**1,953.60**

SYNOPSIS OF RAINFAL

	Height above Sea.	Year commencing Observation.	Years of Observation.	Mean.			
				WINTER.	SPRING.	SUMMER.	TOTAL 12 mos
	Feet.	A.D.	Number	Ins.	Ins.	Ins.	Ins.
Penzance ....Cornwall ..	40	1825	9	17.4	12.2	13.5	43.1
St. Breock.......... " ..		1837	13				41.0
Pencarrow.......... " ..		1841	3				45.3
Plymouth .... Devon ..	30	1826	10	14.2	9.8	11.7	35.7
Goodamoor .... " ..	800	1834	16	23.0	14.0	19.8	56.8
Honiton .... " ..		1841	5	11.3	9.9	12.0	33.2
Exeter .... " ..	141	1825	25	11.0	8.2	10.0	29.2
Bath .... Somerset ..		1841	3				32.4
Hungerford .... Berks ..	320	1838	12				26.9
Reading .... " ..		1832	17	8.2	7.1	10.1	25.4
Gosport .... Hampshire ..	30	1825	7	10.6	8.5	11.1	30.2
Hastings ....Sussex..		1838	12				31.9
Chiswick	25	1825	25	7.4	6.6	10.0	24.0
Cobham Lodge ....Surrey..	80	1825	25	7.7	6.7	10.1	24.5
Greenwich Observatory	143	1838	12				23.9
London (Howard's average)		1800	20	8.9	6.7	9.2	24.8
Tottenham..........Middlesex..	50	1812	7	8.5	7.9	8.4	24.8
Epping ....Essex..		1825	10	8.1	7.3	11.2	26.6
Aylesbury ......Buckingham..		1847	3				28.4
Wellingborough.. Northampton	160	1830	20	7.7	7.7	9.5	24.9
Swaffham Balbeck..Cambridge..		1841	7	6.4	7.8	9.6	23.8
Dickleborough ....Norfolk..	120	1840	10				25.0
Felthorp .... " ..		1843	5				22.6
Boston ....Lincoln..	30	1825	25	6.5	7.2	9.4	23.1
Nottingham (Highfield House) ..		1844	6	7.2	8.7	11.1	27.0
Chapel-en-le-Frith......Derby..	1121	1840	8				43.0
Hyde..............Lancashire..	320	1831	10	11.8	9.8	13.6	35.2
Liverpool.......... " ..		1826	23				34.7
Manchester .... " ..		1813	22	12.2	10.2	14.9	37.3
Fairfield .... " ..	320	1840	8				31.5
Bolton .... " ..	320	1831	10	17.7	12.6	19.2	49.5
Bury.............. " ..	300	1832	13				41.7
Sowerby Bridge ....York..	300	1830	11	9.9	7.3	10.0	27.2
Stubbins.. .... " ..		1830	11				32.3
Moss Lock, near Rochdale	500	1830	11	10.9	7.5	11.9	30.3
Rochdale	500	1832	16				46.7
White Holme, Blackstone Edge ..	1200	1830	18				36.1
Summit...... " " ..	1200	1830	11	14.3	9.5	14.2	38.0
Whitehaven...... Cumberland..	90	1845	3	16.1	11.4	19.5	47.0
Cockermouth		1845	3	13.0	11.2	21.2	45.4
Keswick ......Westmoreland ..	258	1845	3	19.9	16.0	24.2	60.1
Grasmere...... " ..	180	1845	3	48.0	25.3	34.2	107.5
Seathwaite .... " ..		1845	3	55.8	32.5	52.3	140.6
Gatesgarth .... " ..	326	1845	3	44.8	28.0	44.4	117.2
Styehead ...... " ..	1290	1846	2	20.0	27.5	45.3	92.8
Sparkling Tarn " ..	1900	1846	2	22.0	48.7	53.3	124.0
Great Gable.... " ..	2925	1849	2	10.0	43.0	36.4	89.4
Newcastle-upon-Tyne	121	1846	2	5.3	6.8	5.5	17.6
West Denton, near ditto	276	1845	5	9.1	13.0	14.7	36.8
Allenheads "	1300	1843	7	15.6	15.4	16.9	47.9
Applegarth..........Dumfries..		1838	12	10.4	9.1	14.3	33.8
Gilmourton ....Lanark..	600	1845	5	18.8	11.6	17.3	47.7
Glasgow	8	1848	2	15.5	8.3	9.8	33.6
Edinburgh	300	1825	21				25.6
Glencorse (Pentland Hills)......	734	1831	19	11.6	10.2	14.3	36.11

The above Tables give the average maximum and minimum, for periods of four months, with the total for each year of the three periods.

The *Winter* period is for *November*, *December*, *January* and *February*.
The *Spring* " *March*, *April*, *May* and *June*.
The *Summer* " *July*, *August*, *September* and *October*.

IN GREAT BRITAIN.—Table 15

Maximum.					Minimum.				
Winter.	Spring.	Summer.	Total 12 mos.	Year of Maxim.	Winter.	Spring.	Summer.	Total 12 mos.	Year of Minimum
Ins.	Ins.	Ins.	Ins.	A.D.	Ins.	Ins.	Ins.	Ins.	A.D.
22.2	16.7	15.0	53.9	1828	19.5	4.7	10.5	34.7	1826
			51.9	1841				32.0	1840
			57.3	1841				37.9	1844
11.5	14.1	19.4	45.4	1829	6.3	10.0	11.6	27.9	1830
27.0	15.6	27.5	70.1	1839	19.8	9.3	12.5	41.6	1844
11.3	12.4	18.0	41.7	1841	10.3	6.3	8.9	25.5	1844
14.2	12.4	12.7	39.2	1828	6.9	8.4	8.7	24.0	1830
			37.8	1842					
			34.07	1848				19.28	1847
9.0	11.4	12.4	32.8	1848	8.1	3.3	9.8	21.2	1844
15.7	8.7	9.9	34.3	1828	6.9	8.4	8.7	24.0	1830
			43.53	1848				22.36	1847
9.2	7.0	13.5	29.7	1846	4.8	4.7	5.7	15.2	1847
8.6	10.6	12.5	31.7	1848	5.3	5.0	6.5	16.8	1847
			33.2	1841				16.4	1840
8.5	7.2	13.4	29.1	1816	6.1	7.7	5.5	19.3	1814
5.5	8.6	18.1	32.2	1829	5.6	7.4	9.5	22.5	1832
			34.7	1848				22.5	1847
8.1	10.4	14.8	33.3	1848	5.8	3.3	8.7	17.8	1844
7.0	10.1	12.6	29.7	1843	3.6	8.1	7.9	19.6	1842
			32.4	1848				18.4	1847
			25.8	1845				20.0	1845
7.3	6.7	14.8	28.8	1829	5.7	3.2	7.2	16.1	1834
9.9	12.2	16.4	38.5	1848	7.2	4.9	8.0	20.1	1844
			52.3	1841				33.0	1844
13.0	12.8	13.8	39.6	1835	9.2	11.0	10.4	30.6	1832
			49.5	1841				22.2	1826
13.4	11.2	20.5	45.1	1825	14.2	3.9	12.2	30.3	1826
			40.7	1845				24.8	1842
16.0	11.3	31.3	58.6	1831	19.2	7.6	15.4	42.2	1837
			50.6	1835				28.6	1844
11.7	9.5	9.6	30.8	1833	8.8	10.0	7.7	26.5	1832
			40.2	1836				26.1	1832
20.9	2.5	10.3	37.7	1834	6.8	8.4	10.7	25.9	1831
			61.1	1836				34.4	1844
			47.4	1833				24.8	1844
33.6	9.3	12.6	55.5	1834	8.4	8.7	15.6	32.7	1831
16.2	11.9	23.9	52.0	1846	10.3	10.3	14.4	35.0	1847
16.2	13.3	25.9	55.4	1846	9.8	9.1	16.0	34.9	1847
25.7	19.5	29.1	74.3	1846	14.1	13.3	19.6	47.0	1847
4.8	7.1	7.4	19.3	1846	5.7	7.5	3.6	15.8	1847
7.1	13.6	15.0	36.4	1846	11.6	11.6	8.3	31.5	1847
23.2	16.0	19.3	58.5	1848	13.1	10.5	14.7	38.3	1844
11.4	9.3	23.4	44.1	1839	6.9	7.5	9.6	24.0	1847
26.5	13.7	21.1	60.3	1846	8.8	12.8	13.7	35.3	1847
16.4	8.1	9.4	33.9	1849	14.7	8.5	10.3	33.5	1848
			32.59	1827				15.27	1826
14.5	14.2	17.2	45.9	1836	5.4	10.0	8.1	23.5	1847

Where years only are given, the details have not been accessible to the author. The observations are all from authentic data, many kindly furnished from private sources. The Lancashire observations are from Mr. Homersham's reports; the Cumberland and Westmoreland from Mr. Miller, of Whitehaven; Nottingham from Mr. Lowe; Wellingborough from Mr. Bevan, C.E.; Cobham Lodge from Miss Molesworth's diurnal observations.

DETAIL OF MONTHLY RAIN AND

	Year.	January. Total fall.	January. Heavy fall.	February. Total fall.	February. Heavy fall.	March. Total fall.	March. Heavy fall.	April. Total fall.	April. Heavy fall.	May. Total fall.	May. Heavy fall.	June. Total fall.	June. Hvy. fall.
		Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
Glencorse.	1831	.89	..	3.92	3.09	3.29	2.10	2.04	.57	.82	..	2.08	3.2
	1832	.96	.42	1.75	.88	2.23	1.00	1.53	.80	2.00	1.15	4.43	1.27
	1833	.78	.37	4.31	3.22	3.40	1.85	2.75	1.20	1.30	.96	6.18	4.25
	1834	6.05	3.62	2.31	.97	3.69	3.01	1.31	.43	1.15	.33	2.15	.55
	1835	2.07	.85	3.52	2.34	4.08	3.72	1.13	0.59	3.14	1.87	1.66	.32
	1836	6.24	5.58	1.99	1.50	7.32	5.61	2.11	.43	.63	.33	4.15	2.70
	1837	2.81	2.15	3.22	.94	3.10	2.42	3.07	2.46	1.54	.63	2.43	1.87
	1838	2.39	2.26	1.92	1.92	3.12	2.17	3.01	2.41	3.93	3.33	5.55	5.19
	1839	3.88	3.77	3.45	2.71	3.72	2.64	.57	.41	1.47	.81	4.40	3.38
	1840	6.20	5.34	2.58	1.53	.65	..	.35	..	4.35	3.04	3.11	1.54
	1841	2.11	1.84	1.18	..	1.95	.78	1.86	.31	1.74	..	2.54	1.44
	1842	1.32	..	1.89	1.07	4.31	3.52	..	..	2.12	.80	1.76	1.38
	1843	3.51	3.12	2.05	2.04	.99	..	2.66	1.88	3.61	1.87	2.17	1.46
	1844	2.54	1.83	3.04	2.98	3.82	3.63	.81	.39	.71	.37	3.88	2.31
	1845	3.29	2.69	1.33	1.26	2.08	1.57	1.51	.35	2.94	1.34	4.37	3.19
	1846	2.75	1.63	3.24	2.25	2.75	1.49	2.93	.91	2.42	1.56	4.54	3.73
	Average	2.98	2.21	2.60	1.80	3.15	2.22	1.73	.82	2.12	1.15	3.46	2.18
Gilmourton.	1845	4.30	3.75	2.10	1.75	3.00	2.30	1.80	.40	2.20	.40	4.20	3.15
	1846	5.50	4.30	3.40	2.90	5.20	4.15	1.50	.30	2.20	1.45	4.80	4.40
	1847	2.10	1.69	2.10	1.50	1.45	1.20	4.00	3.40	4.10	3.20	3.30	2.70
	Average	3.97	3.25	2.53	2.05	3.22	2.55	2.43	1.37	2.83	1.68	4.10	3.42
Boston.	1831	1.67	1.15	2.50	1.65	1.13	.32	0.90	.72	0.98	.77	1.80	.67
	1832	.77	..	.12	..	1.47	.67	1.60	1.35	2.70	1.95	3.08	1.93
	1833	.64	0.00	4.54	2.58	2.26	.89	2.30	.63	.53	..	3.17	3.26
	1834	2.41	.65	.45	..	.36	..	.64	..	.81	..	1.36	.35
	1835	1.72	.76	2.00	.39	2.68	.79	1.79	.73	2.10	.96	2.04	1.35
	1836	1.11	..	1.87	1.04	2.24	..	1.60	.34	.47	..	1.48	.40
	1837	3.26	2.26	1.47	.36	.41	.35	2.00	1.08	1.08	..	1.79	.96
	1838	1.00	.90	1.62	.72	1.09	.	1.68	.79	1.88	.69	2.86	1.07
	1839	1.40	.50	1.10	.51	2.59	1.99	.75	.30	.66	..	4.58	3.41
	1840	1.25	.36	1.28	..	.70	.31	.54	..	2.46	1.19	1.99	.71
	1841	1.55	.85	1.58	.58	1.20	.32	1.69	.68	1.42	.72	3.05	2.42
	1842	2.40	2.40	1.48	.31	2.08	.72	1.34	.87	2.48	1.22	1.05	.51
	1843	1.34	.36	2.16	1.34	.62	..	1.39	1.54	3.80	2.89	1.78	1.10
	1844	1.68	.40	1.80	1.16	1.89	.65	.39	..	.52	.35	1.49	.79
	1845	1.42	.68	.90	..	1.98	1.51	1.12	.34	3.37	2.14	2.04	1.13
	1846	2.50	1.32	.57	..	.64	..	3.23	2.32	1.45	0.40	1.08	.95
	1847	.98	..	1.21	.87	.94	.37	1.77	.36	5.41	3.75	2.85	1.50
	Average	1.59	.740	1.56	.674	1.42	.523	1.42	.709	1.89	.999	2.24	1 32

AVERAGE OF RAIN FOR 1844, 1845, 1846 & 1847,

Amounting to .4 inch and upwards in 24 hours; from Mr. Homersham's Report on Supply of Water to Manchester.

Locality.	Above Sea.	Rain per Ann.	Ditto .4 in. and above.	Days of .4 in. and above.	Total Days of Rain.
Manchester..........	120	36.49	16.25	26	206
Marple..............	531	36.56	20.00	31	122
Combs...............	720	45.80	27.60	43	160
Chapel-en-le-Frith ..	1121	39.92	21.80	38	136

GREATEST DEPTH IN ONE DAY.

	1844.	1845.	1846.	1847.
Manchester............	1.36	1.48	0.77	1.20
Marple................	2.90	2.10	0.80	2.30
Combs.................	1.50	2.00	1.00	2.00
Chapel-en-le-Frith	1.10	1.70	1.20	1.30
Glencorse, October 3rd..	..	2.14	3.37	July 6th.
Gilmourton „	..	1.50	2.50	„

Note.—There fell without intermission, on June 23 and 24, 1846, at Glencorse 1.83 and 1.35 inches; at Gilmourton 1.50 and 1.50 inches.

PROPORTION OF HEAVY FALL.—TABLE 15a

July.		August.		Sept.		Oct.		Nov.		Dec.				
Total fall.	Hvy. fall.	Total fall.	Hvy. fall.	Total fall.	Hvy. fall.	Total fall.	Hvy. fall.	Total fall.	Hvy. fall.	Total fall.	Hvy. fall.	Total Annl. fall.	Total Heavy fall.	Total No. of Days Heavy fall.
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	
2.98	2.22	3.93	3.27	2.45	1.24	3.76	1.82	3.20	1.61	2.00	.38	31.36	16.62	33
1.62	1.05	6.55	5.41	1.31	..	7.83	6.64	1.83	1.14	3.67	2.49	35.71	22.25	34
3.22	2.48	1.91	1.07	2.13	1.27	2.32	1.90	3.10	1.50	8.28	6.55	39.70	26.62	46
5.13	4.52	1.85	.63	5.29	4.32	3.17	2.04	2.92	2.08	2.70	2.28	37.72	24.78	39
2.29	.89	2.64	2.14	7.48	5.82	4.85	3.18	3.59	2.10	2.66	1.87	39.11	25.69	43
7.85	6.33	2.73	2.23	3.88	2.57	2.73	1.92	4.73	4.08	4.72	3.70	49.08	36.98	56
6.22	4.84	5.12	4.69	2.74	2.34	5.50	4.20	2.46	1.12	3.40	2.29	41.61	29.95	48
3.00	.12	4.33	3.67	4.84	4.13	3.46	3.29	3.20	2.90	1.70	.59	40.45	31.98	48
4.30	3.77	3.06	1.54	3.88	2.31	2.90	2.08	3.13	2.15	2.10	1.28	36.86	26.85	45
5.45	3.69	2.50	1.60	4.23	2.28	2.26	1.38	3.89	3.06	1.13	.39	36.70	23.85	41
4.41	2.19	5.50	4.27	3.25	1.43	6.65	5.08	2.68	2.03	4.65	4.15	38.51	23.52	41
1.85	.70	1.86	1.01	2.73	1.72	1.56	1.14	2.05	1.28	4.22	3.22	25.67	15.84	33
4.34	3.21	2.44	.51	1.35	.57	5.23	3.67	4.05	2.34	.94	5.05	33.34	25.72	33
2.51	1.82	2.26	.95	2.99	2.18	1.78	.90	5.59	4.44	.20	..	30.12	21.80	40
2.54	1.01	5.38	3.71	4.83	4.02	8.01	7.45	2.90	1.50	4.43	3.25	43.63	31.34	51
5.59	4.21	5.30	4.59	1.99	1.18	3.84	2.55	2.08	1.05	1.02	.77	38.45	25.92	38
3.95	2.69	3.58	2.58	3.46	2.33	4.12	3.08	3.21	2.15	3.00	2.39	37.38	25.61	41.7
2.80	1.95	4.10	2.37	5.80	5.15	11.70	11.35	7.80	7.10	9.80	9.20	59.60	48.87	74
6.10	4.90	6.30	5.90	2.50	2.05	5.20	3.80	2.40	1.40	2.20	1.55	47.30	37.10	63
2.10	1.50	1.30	.40	4.40	2.60	5.90	4.90	6.00	4.95	4.50	3.20	41.25	31.24	62
3.67	2.78	3.90	2.89	4.23	3.60	7.60	6.68	5.40	4.48	5.50	4.65	49.38	39.07	66.3
2.35	1.55	5.03	4.54	2.90	2.12	2.46	1.19	1.95	.82	1.96	.38	25.57	15.88	30
1.55	1.00	3.89	2.14	.90	.49	1.85	1.08	2.59	.90	2.03	.32	22.55	9 73	25
.60	.30	2.02	1.04	1.49	.63	2.23	1.49	.86	.67	1.98	.30	22.62	11.89	23
3.84	3.18	1.39	.92	1.30	.75	.67	..	.79	.50	.64	.32	14.66	6.67	12
1.20	.87	0.84	.40	2.61	1.62	3.58	2.64	1.74	.72	.27	..	22.57	11.23	25
1.60	.34	1.22	.33	2.38	.68	2.73	1.95	3.46	1.93	1.22	.78	21.38	7.79	16
1.88	.83	3.90	3.05	1.70	.86	1.96	1.06	1.55	.34	2.58	1.29	23.58	12.44	21
1.64	..	2.85	1.33	1.82	1.03	1.35	.92	1.17	.30	0.79	.34	18.95	8.09	16
4.36	3.50	3.47	2.28	2.16	.42	2.41	1.31	3.23	2.07	1.77	.35	28.48	16.64	29
2.76	1.54	1.22	.40	1.90	.78	1.63	.58	2.03	.46	.85	..	18.61	6.01	14
3.74	1.92	2.85	1.92	3.43	2.19	2.97	1.62	2.11	.98	1.67	..	27.26	14.20	27
3.57	2.66	1.05	.64	3.72	2.20	.88	..	3.80	1.87	.88	.63	24.73	14.03	21
2.40	1.37	4.02	2.92	0.47	..	3.35	1.61	2.84	1.67	.12	..	24.29	14.89	30
2.63	1.49	2.57	1.67	2.50	1.54	2.37	1.58	3.40	2.85	.40	..	21.64	12.48	24
2.51	.78	4.85	3.82	1.26	.73	1.39	.69	1.13	.32	2.32	.73	24.29	12.87	28
1.98	1.22	3.08	2.44	.79	.37	4.38	2.64	1.70	1.18	2.00	1.46	23.40	14.28	29
.86	.68	1.46	.79	1.54	.88	2.52	1.78	1.32	.53	3.06	2.14	23.92	13.65	23
2.32	1.37	2.64	1.80	1.93	1.02	2.28	1.30	2.10	1.06	1.44	.53	22.30	11.93	23.11

The above Table shows the quantity of rain in each month of the years specified, placed in juxtaposition with the amount of rain given by falls of ·3 inch and upwards, as extracted from the diurnal registries.

The places are Glencorse in the Pentland Hills, 734 feet above the sea.
„ Gilmourton „ Avondale „ 600 „ „
„ Boston, Lincolnshire, about 40 „ „

The two former give fair specimens of rain-fall in ordinary hill districts. The last gives the average rain in the flat central parts of Great Britain.

The following Table of Rain in Ireland is extracted from a very useful treatise on Hydraulic Engineering, by John Dwyer, C.E., of Dublin.

LOCALITY.	No. of Yrs.	Average.
Dublin	6	30.87 Inches.
Belfast	6	34.96 „
Castlecomer	18	37.80 „
Cork County	6	40.20 „
Cork City	6	36.03 „
Derry	7	31.12 „

VELOCITIES—TABLE 16

Feet per Minute and miles per Hour.

For feet per second divide by 60
For inches per second divide by 5
For miles per hour multiply by .01136

Feet per min.	Miles per hour	Feet per min.	Miles per hour
10	.1136	280	3.181
11	.1250	300	3.408
12	.1364	320	3.635
13	.1478	340	3.862
14	.1592	360	4.089
15	.1706	380	4.317
16	.1820	400	4.544
17	.1934	420	4.771
18	.2048	440	4.998
19	.2162	460	5.225
20	.2272	480	5.453
25	.2840	500	5.680
30	.3409	550	6.248
35	.3981	600	6.814
40	.4554	650	7.384
45	.5118	700	7.952
50	.5682	750	8.420
55	.6250	800	8.988
60	.6819	850	9.608
65	.7387	900	10.228
70	.7955	950	10.796
75	.8531	1000	11.365
80	.9108	1056	12.
85	.967	1232	14.
90	1.024	1408	16.
95	1.080	1584	18.
100	1.137	1760	20.
105	1.193	1936	22.
110	1.250	2112	24.
115	1.307	2288	26.
120	1.364	2464	28.
125	1.421	2640	30.
130	1.478	2816	32.
135	1.535	2992	34.
140	1.592	3168	36.
145	1.649	3344	38.
150	1.706	3520	40.
155	1.763	3696	42.
160	1.820	3872	44.
165	1.877	4048	46.
170	1.934	4224	48.
175	1.991	4400	50.
180	2.048	4840	55.
185	2.105	5280	60.
190	2.162	5720	65.
195	2.217	6160	70.
200	2.272	6600	75.
220	2.499	7040	80.
240	2.726	7920	90.
260	2.953	8800	100.

GRADIENTS—TABLE 17

Rate and Fall in Feet per Mile and per Chain.

For feet per mile divide 5280 by the rate.
For feet per chain divide 66 by the rate.

Rate.	FALL.		Rate.	FALL.	
one in	Feet per mile.	Feet per chain.	one in	Feet per mile.	Feet per chain.
5	1056	13.2	180	29.3	.366
6	880	11.0	182.1	29.0	.362
7	754.2	9.43	188.6	28	.349
8	666	8.25	190	27.8	.347
9	586.6	7.40	195.6	27	.337
10	528.0	6.66	200	26.4	.330
12	440	5.50	211.2	25	.312
14	377.1	4.71	220	24	.300
16	330	4.13	229.6	23	.288
18	293	3.66	240	22	.275
20	264	3.30	251.4	21	.262
25	211.2	2.64	264	20	.250
30	176	2.20	267.9	19	.237
35	150.8	1.88	293.3	18	.224
40	132	1.65	310.6	17	.212
45	117.3	1.46	330.0	16	.200
50	105.6	1.32	352.0	15	.187
55	96.0	1.20	377.1	14	.175
60	88.0	1.10	406.1	13	.162
65	81.2	1.01	440.0	12	.150
70	75.4	.94	480.0	11	.138
75	70.4	.88	528.0	10	.125
80	66.0	.82	586.7	9	.112
82	64.4	.80	660.0	8	.100
84	62.8	.78	754.3	7	.0874
86	61.4	.76	880.0	6	.0750
88	60.0	.75	960	5.50	.0690
90	58.6	.73	1056	5.00	.0625
92.6	57.0	.71	1173	4.5	.0562
95	55.5	.69	1320	4.0	.0500
96	55.0	.68	1508	3.5	.0437
98	53.8	.67	1760	3.0	.0375
100	52.8	.66	1920	2.75	.0345
101.5	52.0	.65	2112	2.50	.0312
103.5	51.0	.63	2346	2.25	.0281
105.6	50.0	.62	2640	2.	.0250
110	48.0	.60	3017	1.75	.0218
115	45.9	.57	3520	1.5	.0187
120	44.0	.55	4224	1.25	.0156
125	42.2	.52	5280	1.	.0125
				inches.	
130	40.6	.507	5760	11	.0111
135	39.1	.488	6336	10	.0104
140	37.7	.471	7040	9	.0093
145	36.4	.455	7585	8	.0087
150	35.2	.440	9051	7	.0073
155	34.0	.425	10560	6	.0062
160	33.0	.410	12672	5	.0052
165	32.0	.400	15840	4	.0043
170	31.0	.388	21120	3	.0031
176	30.0	.375	31680	2	.0021
			63360	1	.0010

COMPARATIVE MEASURES.—TABLE 13

CHAINS, YARDS, AND FEET,

With their Reciprocal Equivalents, and a Table of Reductions for Slopes.

Link = 7.92 *inches.* *Chain* = 792 *inches.*

Chains into Feet.				Feet into Chains.			For each 100 on Slope.		
Chains	Links.	Yards.	Feet.	Feet.	Yards.	Links.	Rate of Fall.	Angle. Deg. Min.	Deduct.
0.	1	.22	.66	.10	.033	0.15		1.0	.015
0.	2	.44	1.32	.20	.066	0.30		2.0	.061
0.	3	.66	1.98	.25	.082	0.38	1 in 20	2.52	.126
0.	4	.88	2.64	.30	.010	0.45	„ 19	3.01	.137
0.	5	1.10	3.30	.40	.133	0.60	„ 18	3.11	.153
0.	6	1.32	3.96	.50	.166	0.76	„ 17	3.22	.173
0.	7	1.54	4.62	.60	.200	0.91	„ 16	3.35	.198
0.	8	1.76	5.28	.70	.233	1.06	„ 15	3.49	.225
0.	9	1.98	5.94	.75	.250	1.13	„ 14	4.05	.254
0.	**10**	**2.20**	**6.60**	**.80**	**.266**	**1.21**	**„ 13**	**4.24**	**.297**
0.	20	4.40	13.20	.90	.300	1.36	1 in 12	4.46	.343
0.	30	6.60	19.80	1.00	.33	1.51	„ 11	5.12	.406
0.	40	8.80	26.40	2.0	.66	3.0	„ 10	5.45	.503
0.	50	11.00	33.00	3.0	1.000	4.5	„ 9	6.20	.610
0.	60	13.20	39.60	4.0	1.33	6.0	„ 8	7.10	.781
0.	70	15.40	46.20	5.0	1.66	7.5	„ 7	8.10	1.014
0.	80	17.60	52.80	6.0	2.00	9.1	„ 6	9.30	1.373
0.	90	19.80	59.40	7.0	2.33	10.6		10.00	1.519
1.	00	22.00	66.00	8.0	2.66	12.1	1 in 5	11.20	1.950
2.		**44.00**	**132**	**9.0**	**3.00**	**13.6**		**12.00**	**2.185**
3.		66.00	198.	10.0	3.33	15.1		13.00	2.563
4.		88.00	264.	15.0	5.00	22.7	1 in 4	14.02	2.980
5.		110.	330.	20.0	6.66	30.3		15.00	3.408
6.		132.	396.	24.0	8.00	36.3		16.00	3.874
7.		154.	462.	27.	9.00	40.9		17.00	4.369
8.		176.	528.	30.	10.00	45.4		18.00	4.894
9.		198.	594.	33.	11.00	50.0	1 in 3	18.26	5.130
10.		220.	660.	36.	12.00	54.5		19.00	5.448
20.		440.	1320.	39.	13.00	59.1		20.00	6.031
30.		**660.**	**1980.**	**40.**	**13.33**	**60.6**		**21.00**	**6.642**
35.		770.	2310.	42.	14.0	63.3		22.00	7.282
40.		880.	2640.	45.	15.00	68.2		23.00	7.949
45.		990.	2970.	48.	16.00	72.7		24.00	8.645
50.		1100.	3300.	50.	16.66	75.7		25.00	9.369
55.		1210.	3630.	51.	17.00	77.3		26.00	10.120
60.		1320.	3960.	54.	18.00	81.8	1 in 2	26.34	10.570
65.		1430.	4290.	57.	19.00	86.3	„	27.00	10.900
70.		1540.	4620.	60.	20.00	90.9	„	28.00	11.645
75.		1650.	4950.	63.	21.00	95.4	1 in 1½	33.41	16.667
80.		**1760.**	**5280.**	**66.**	**22.00**	**100.**	**1 „ 1**	**45.00**	**29.290**

USEFUL WEIGHTS AND MEASURES.—TABLE 19

Inches and Fractions expressed in Decimals of a Foot.

NOTE.—The first column gives the decimals corresponding to the fractional parts of units in the next column; thus three-sixteenths is .1875 of an inch.

The remaining columns give the decimals of a foot corresponding to inches and parts: thus 5⅜ inches = .448 of a foot.
1⅛ „ = .094 „

Decimals of Unity or an Inch.	Inches.	0	1	2	3	4	5	6	7	8	9	10	11
	Parts.	Foot.	Foot.	Foot.	Foot.	Foot.	Foot.	Foot.	Foot.	Foot.	Foot.	Foot.	Foot.
	0 – 0		.083	.166	.250	.333	.416	.500	.583	.666	.750	.833	.916
.0625	1 – 16	.005208	088	172	255	338	422	505	588	671	755	838	922
.1250	1 – 8	.010416	094	177	260	344	427	510	594	677	760	844	927
.1875	3 – 16	.015625	099	182	265	349	432	515	599	682	765	849	932
.25	1 – 4	.020833	104	187	271	354	437	520	604	687	771	854	937
.3125	5 – 16	.026041	109	193	276	359	443	526	609	692	776	859	943
.3750	3 – 8	.03125	114	198	281	364	448	531	614	697	781	864	948
.4375	7 – 16	.036458	120	203	286	371	457	536	620	703	786	870	953
.5	1 – 2	.04166	125	208	291	375	458	541	625	708	791	875	958
.5625	9 – 16	.046875	130	213	297	380	463	547	630	713	797	880	963
.6250	5 – 8	.052083	135	219	302	385	469	552	635	718	802	885	969
.6875	11 – 16	.057291	140	224	307	390	474	557	640	723	807	890	974
.75	3 – 4	.06250	146	229	312	396	479	562	646	729	812	895	979
.8125	13 – 16	.067708	151	234	318	401	484	568	651	734	818	901	984
.8750	7 – 8	.072916	156	239	323	406	489	573	656	739	823	906	989
.9375	15 – 16	.078125	161	245	328	411	495	578	661	744	828	911	995

Miscellaneous Numbers and Rules.

Length of an Arc = No. of Deg. × Rad. × .01745
Circum. of Circle = Dia. × 3.1416
Area „ = Dia^2 × .7854
Ellipse Area. = T. Axis × C. Axis × .7854
Spheroid Cube = Rev. Axis 3 × f. Axis × .5236
Sphere Surface = Dia^2 × 3.1416
„ Cube = Dia^3 × .5236
Parabola Area = ⅔rds of base × height
Paraboloid Cube = ½ base × height
Cone & Pyr. Sur. = ½ girt. of base × slant height
„ „ Cube = area of base × ⅓ height

Grains in 1 lb. Avoirdupois ...... = 7000
Cubic Inch. in Imperial Gallon .. = 277.274
Do. in Imperial Bushel .. = 2218.192
Lbs. in the Imperial Gallon w ... = 10·003
Lbs. in the Cubic Foot .... = 62.5
Imperial Gallons in 1 Cubic Foot .. = 6.23
Miles in 1 Degree .... = 69.044
Length of Seconds Pend. Lat. 51° = 39.13938
„ ½ „ „ = 9.785
„ ⅓ „ „ = 4.349
„ ¼ „ „ = 2.446

Reduction of Foreign Measures into English.

French.	*English.*
Millimetre ..	.. = 0.03937 inches
Centimetre ..	.. = 0.39371 „
Decimetre ..	.. = 3.93708 „
Metre ..	.. = 39.37079 „
„ ..	.. = 3.2808 feet
„ ..	.. = 1.0936 yards
Myriametre ..	.. = 6.2138 miles
Toise (old) ..	.. = 76.68 inches
Foot (pied.)	.. = 12.78 „
Inch (pouce)	.. = 1.06578 „
Line (ligne)	.. = .088815 „
Cubic Metre	.. = 35.317 cubic feet
Kil. per sq. Millm.	= 1422. lbs. per sq. inch
Litre	.. = 61.028 cubic inches
Metre, square	.. = 1.196 yards square
„ „	.. = 10.764 feet square

French.	*English.*
Are (land) ..	.. = 3.95 perches
„	.. = 119.6 sq. yards
„	.. = 0.0247 acre
Hectare	.. = 2.471143 „
Capacity.	
Litre	.. = 1.760773 pints
„	.. = 0.2200967 gallons
Decalitre ..	.. = 2.201 gallons
Hectolitre ..	.. = 22.01 „
„ ..	.. = 2.7512 bushels
Weight.	
Decigramme	.. = 1.5428 grains
Gramme ..	.. = 15.428 „
Kilogramme	.. = 2.6803 lbs. Troy
„	.. = 2.2055 lbs. Avoirdupois
Quintal	.. = 220.55 „ „

Various Nations,	*English.*
Berlin foot	.. = 12.19 inches
Copenhagen	.. = 12.35 „
Dantzic foot	.. = 11.29 „
Hamburgh ft.	.. = 11.29 „
Naples Palm	.. = 10.38 „
Roman foot	.. = 11.60 „
Russian „	.. = 13.75 „
Spanish „	.. = 11.12 „
„ vara	.. = 33.272 „
Eng. mile (5280 ft.)	= 1760 yards

Various Nations.	*English*
Nautic. mile (6075.6 ft.)	= 2025.2 yards
Flanders mile	.. = 6869 „
French league	.. = 4263 „
„ nautical	.. = 6075 „
German long mile	.. = 10126 „
short „	.. = 6859 „
Irish „	.. = 3038 „
Prussian „	.. = 8468 „
Russian verst	.. = 1167 „
Spanish league	.. = 4635 „

Areas of Segments of a Circle, and Lengths of Circular Arcs,

Taking diameter as unity for Areas, and base of segments as unity for Lengths.

RULE FOR AREAS.—Multiply the area of the circle of which the given segment is a part, by the tabular area, the result will be the area required.

V. Sin.	Area.	Length.	V. Sin.	Area.	Length.	V. Sin	Area.	Length.
.01	.0013	..	.18	.0961	1.084			
.02	.0037	..	.19	.1039	1.093	.35	.2450	1.300
.03	.0068	..	.20	.1118	1.103	.36	.2545	1.316
.04	.0105	..	.21	.1199	1.114	.37	.2642	1.332
.05	.0147	..	.22	.1281	1.124	.38	.2739	1.349
.06	.0192	1.006	.23	.1364	1.135	.39	.2836	1.366
.07	.0241	1.018	.24	.1449	1.147	.40	.2934	1.383
.08	.0294	1.014	.25	.1535	1.159	.41	.3032	1.401
.09	.0350	1.020	.26	.1623	1.171	.42	.3130	1.418
.10	.0409	1.026	.27	.1711	1.184	.43	.3229	1.437
.11	.0470	1.032	.28	.1800	1.197	.44	.3328	1.455
.12	.0534	1.038	.29	.1890	1.212	.45	.3428	1.474
.13	.0600	1.044	.30	.1981	1.225	.46	.3527	1.493
.14	.0668	1.051	.31	.2074	1.239	.47	.3627	1.512
.15	.0739	1.059	.32	.2167	1.254	.48	.3727	1.531
.16	.0811	1.067	.33	.2260	1.269	.49	.3827	1.551
.17	.0885	1.075	.34	.2355	1.284	.50	.3927	1.571

Length of Degrees and Minutes of an Arc,

RADIUS BEING UNITY.

Deg.	Length.	Min.	Length.
1	0.0174533	1	0.0002909
2	0.0349066	2	0.0005818
3	0.0523599	3	0.0008727
4	0.0698132	4	0.0011636
5	0.0872665	5	0.0014545
6	0.1047198	6	0.0017454
7	0.1221731	7	0.0020363
8	0.1396264	8	0.0023272
9	0.1570797	9	0.0026181
10	0.1745330	10	0.0029090

Height of Apparent above True Level.

The Correction for Refraction is to be applied when necessary.

Dist. Chns.	Subtract Feet.	Dist. Chns.	Subtract Feet.	Dist. Chns.	Subtract Feet.
1	0.00	11	0.012	21	0.045
2	0.00	12	0.015	22	0.050
3	0.001	13	0.018	23	0.055
4	0.002	14	0.020	24	0.060
5	0.003	15	0.023	25	0.065
6	0.004	16	0.027	26	0.070
7	0.005	17	0.030	27	0.075
8	0.007	18	0.033	28	0.080
9	0.008	19	0.037	29	0.085
10	0.010	20	0.041	30	0.090

Square Yards in Decimals of an Acre.

Sq. Yards	Decimal of an Acre.	Sq. Yards	Decimal of an Acre.	Sq. Yards	Decimal of an Acre.
1	.000206				
2	.00041	20	.0041	200	.0413
3	.00062	30	.0062	300	.0619
4	.00083	40	.0083	400	.0826
5	.00103	50	.0103	500	.1033
6	.00124	60	.0124	600	.1239
7	.00144	70	.0144	700	.1446
8	.00165	80	.0165	800	.1653
9	.00185	90	.0185	900	.1859
10	.00206	100	.0206	1000	.2066

BRICKWORK.

1 Rod takes 4,200 to 4,500 Bricks; 270 to 300 Bricks = 1 ton. A rod is 306 c. ft., or 11.33 c. yards.

Wall sup. feet.	Contains Bricks.	
	At 1 Brick.	At 1½ Brick.
1	11	16
2	22	33
3	33	49
4	44	66
5	55	82
6	66	99
7	77	115
8	88	132
9	99	148
10	110	165

METALS, BUILDING MATERIALS, FLUIDS, &c.

TABLES OF VARIOUS PROPERTIES.

The different qualities of materials in these tables express an average, from the best authorities, and in many cases from original experiments. Allowance must be made, in many cases, for the nature of the materials, when applying the tables, as many are in their nature variable.

Tenacity varies as the sectional area.

Transverse strength as the square of the depth ÷ by the length for rectangular beams; or as the cube of the diameter ÷ by the length in cylindric beams.

Resistance to crushing increases generally in a much more rapid ratio than the area.

The multipliers for transverse strength give the breaking weight for rectangular beams, *fixed at one end and loaded at the other*; thus, $\frac{\text{Tab. No.} \times b \times d^2}{\text{length}}$ = breaking weight in lbs.;
When *fixed at one end and uniformly loaded*, take *twice* the tabular number.
When *supported at both ends and loaded in the middle*, take *four times* the tabular number.
When *supported at both ends and uniformly loaded*, take *eight times* the tabular number.

NOTE.—Safe load should not be more than one-fourth to one-sixth of the breaking weight.

METALS.	Specific Gravity.	Weight of a cubic Foot in lbs. avds.	Melting Point. Fah.	Tenacity per Sq. Inch in lbs.	Crushing Force per Sq. Inch.	Expansion 32° to 212°.
Antimony, Cast	6.600	418	810°	1066		1.0011
Bismuth, Cast	9.810	613	472	3250		1.0014
Brass	8.399	525	1869	17968	10304	1.0020
Copper	8.607	538	2548	19072*		1.0018
Gold, Pure	19.253	1203	2590	20450		1.0016
Gold Coin	17.647				TONS.	
Iron, Cast (variable)	7.104	444	3479	13440 to 23000	40 to 50	1.0011†
Iron, Swedish	7.600			68000		
Iron, Malleable, best Bar	7.700	481		60000‡	20 to 30	1.0012
Lead	11.446	717	612	1824		1.0028
Mercury, Fluid	13.568	848				1.0160§
Platinum, Purified	20.250	1219	wire	... 56000		1.0009
Silver, Standard	10.300	644	1280°	40900		1.0019
Steel, Soft	7.800	490		120000		1.0011
Tin	7.291	455	442	5322		1.0022
Zinc	7.028	439	700°	16090 to 20000		1.0029

* Wrought Copper Tenacity 33,000 lbs. † Shrinks, when cast, ⅛ inch per foot.

‡ Tenacity of Common Bar (say) 15 tons per square inch; Elastic Power (say) two-thirds of ultimate strength; Best Iron one-half. Compression begins at 10 to 12 tons.

Multipliers for transverse strength.
Cast Iron average 8,000.
Wrought Iron average 16,000.

§ Boils at 660°; expansion of glass tube 32° to 212° = 1.0008.

WEIGHT, STRENGTH, &c. OF MATERIALS.—TABLE 20

BUILDING AND OTHER MATERIALS.	Specific Gravity.	Weight of a Cubic Foot in lbs.	No. of Feet in a Ton.	Crushing force per Square Inch, in lbs.
Alabaster	2.699	168	13.3	
Basalt	2.864	179	12.5	
Brick	1.557	97	23.0	1500
	2.168	135	16.6	2000
Brickwork, in Cement	1.680	105	21.4	
Do. in Mortar	1.568	98	22.9	
Concrete, Portld. Cement	2.272	142	15.8	
Do. common Lime	1.900	120	18.6	
Cement, Portland	1.280	80	28.0	
Do. Roman	1.040	65	34.4	
Chalk	2.315	145	15.4	500
Clay, Medway	1.440	90	25.0	
Do. common	2.000	125	17.0	
Coal, Newcastle	1.257	78	28.7	
Do. Welsh	1.337	83	27.	
Do. Cannel	1.300	81	27.6	
	1.400	89	25.2	
Coke	.744	46		
Earth, rammed	1.584	99	22.6	
Flint	2.630	164		
Flooring	..	..		
Glass, plate	2.453	153		
Gravel	1.900	120	18.6	
Granite, Cornish	2.662	166	13.5	
Do. Aberdeen	2.625	164	13.5	8000
Do. Red Egyptian	2.654	166	13.5	
Lime, of Stone	.483	53	42.2	
Do. of Chalk	.704	44	51.0	
Limestone, Bolsover	2.316	145	15.4	
Do. Blue lias	2.467	154	14.5	
Do. Plymouth	2.677	169	13.2	
Do. Statuary marble	2.638	165	13.5	6400
Do. Purbeck	2.601	163	13.7	
Marl	1.600	100	22.4	
	2.800	170	13.2	
Mortar	1.751	107	21.0	
Oolite, Bath	1.839	115	19.5	
Do. Portland	2.145	134	16.6	3729
Porphyry	2.765	173	12.9	
Pozzolano	1.444	90	25.0	
Sand, River	1.886	118	19.2	
Roofing	..	..		
Sandstone, Bramley Fall	2.506	156	14.4	
Do. Darley Dale	2.628	164	13.5	
Do. Craigleith	2.266	142	15.8	5800
Do. York Landing	2.320	145	15.4	
Serpentine, Green	2.574	164	13.6	
Shingle	1.424	89	25.2	
Slate, Welsh and Valencia	2.888	180	12.4	
Do. Westmoreland	2.791	174	12.7	
Sulphur	2.033	127	17.6	
Tile	1.815	113	20.0	

REMARKS.

Crushing force of fire-bricks as high as 5,500 lbs. (Buchanan.)

Mortar.

c feet
1 Dorking Lime
3 Sand
1 Water
5 Total, will make 2.9 cubic feet of Mortar, or dry materials to Mortar, as 4 to 3, nearly.

Flooring.

80 lbs. per foot superficial.

Glass.

Expansion 32° to 212°—.00086.

Crushing Weights

are probably a minimum, as strength increases more than as the square of the dimensions.

Lime.

70 lbs. p. bsh. Stone
56 lbs. „ Chalk

Sand

Shrinks one-third if wetted.

Roofing.

For force of wind take .. *per sq. ft.* 40 lbs.
Slating .. 12 „
Plain tiling 17 „

Great wrought-iron roof of Lime-street railway station, 153.5 ft. span; length 374 feet; principals 21.5 ft. apart; weight of iron in each principal 10 tons; cost £22 per square; proof load 72 lbs. per foot sup.

WEIGHT, STRENGTH, &c. OF MATERIALS.—TABLE 20

TIMBER.	Specific Gravity.	Weight of a Cubic Foot in lbs.	No. of Feet in a Ton.	Tenacity per square inch in lbs.	Crushing force per square inch in lbs.	Multiplier for Transverse Strength.
Alder	.800	50.0	44.8	14186	6895	..
Ash	.767	49.0	45.7	17207	9023	2026
Beech	.777	43.12	51.0	16817	9048	1560
Birch	.792	49.5	45.2	15000	4567	1900
Box	.960	60.0	37.3	19891	10299	..
Ebony	1.250	70.4	30.0	..	..	..
Cork	.240	15.0	..	..	..	..
Elm	.588	36.7	61.0	13489	10331	1030
Larch	.522	32.6	68.6	10220	..	900
Lance Wood	1.022	63.9	35.1	24696	..	..
Lignum Vitæ	1.220	76.2	29.3	11800	..	..
Mahogany, Spanish	.800	50.0	44.8	16500	8198	..
Do. Honduras	.560	35.0	64.0	8700	..	..
Oak, English	.934	58.3	38.3	17300	..	1800
Do. Canadian	.872	54.5	41.1	10253	..	1760
Do. Dantzic	.756	47.2	47.4	12780	..	1450
Do. African	.972	60.7	36.8	..	..	2000
Green Heart	1.000	62.5	35.0	..	..	2700
Pine, Red	.657	41.0	54.5	..	5375	1340
Do. American Yellow	.461	28.8	77.7	..	5445	..
Plane Tree	.640	40.0	56.0	11700	..	..
Sycamore	.690	43.1	52.0	13000	..	..
Teak	.657	41.0	54.5	15000	12101	2460
Walnut	.671	41.9	53.4	8130	6645	..
FLUIDS.			Boiling Point.	Expansion 32° to 212°.	REMARKS.	
Alcohol, Commercial	.837	52.3	173°	1.110		
Ammonia	.897	56.1	..	..		
Ether, Sulphuric	.739	46.3	100°	1.070		
Milk	1.032	64.5	..	..		
Muriatic Acid	1.194	75.0	222°	1.060		
Naptha	..	..	..	..		
Olive Oil	.915	57.2	..	1.080		
Sperm Oil	.872	54.5	..	1.080		
Sulphuric Acid	1.841	115.6	..	1.060		
Turpentine, Spirit	.870	54.9	316°	1.070		
Water, Rain	1.000	62.5	212°	1.047	at 77° exp. 1.003	
Do. Sea	1.026	64.1	213°.2	...		
Ice	.940	58.7				
GASES.		Grains.				
Air	1.000	525.0	..	1.375	To convert moist	
Ammoniacal Gas	0.596	319.8	..	Do.	air or gas into	
Carbonic Acid	1.524	800.1	..	Do.	dry:—	
Chlorine	0.470	246.7	..	Do.	Deg. Deg. Multiply	
Carburetted Hydrogen	0.420	220.5	..	Do.	53 to 57 - .986	
Hydrogen	0.069	43.7	..	Do.	57 to 63 - .980	
Oxygen	1.103	627.8	..	Do.	64 to 69 - .976	
Sulphureous Acid	2.234	1207.9	..	Do.	69 to 73 - .974	

WEIGHT OF IRON, &c.—TABLE 21

MALLEABLE IRON, FOR ONE FOOT IN LENGTH.

For weight of cast iron, multiply by .95
" steel " 1.02
" copper " 1.13

For weight of brass multiply by 1.08
" lead " 1.50
" zinc " .92

ROUND AND SQUARE BAR.

Size.	Round.	Square.	Size.	Round	Square
ins.	lbs.	lbs.	ins.	lbs.	lbs.
1/2	**0.7**	**0.8**	**5**	**67**	**84**
5/8	1.0	1.3	5 1/8	69	88
3/4	1.5	1.9	5 1/4	73	93
7/8	2.0	2.6	5 3/8	76	97
1	**2.7**	**3.4**	**5 1/2**	**81**	**102**
1 1/8	3.4	4.3	5 5/8	84	107
1 1/4	4.2	5.3	5 3/4	88	111
1 3/8	5.0	6.4	5 7/8	91	116
1 1/2	**6.0**	**7.6**	**6**	**95**	**121**
1 5/8	7.0	8.9	6 1/4	103	132
1 3/4	8.1	10.4	6 1/2	112	142
1 7/8	9.3	11.9	6 3/4	121	154
2	**10.6**	**13.5**	**7**	**130**	**165**
2 1/8	12.0	15.3	7 1/4	139	177
2 1/4	13.4	17.1	7 1/2	149	190
2 3/8	15.0	19.1	7 3/4	159	203
2 1/2	**16.7**	**21.1**	**8**	**170**	**216**
2 5/8	18.3	23.3	8 1/4	180	230
2 3/4	20.1	25.6	8 1/2	192	244
2 7/8	21.9	27.9	8 3/4	203	258
3	**23.9**	**30.4**	**9**	**215**	**273**
3 1/8	25.9	33.0	9 1/4	227	289
3 1/4	28.0	35.7	9 1/2	239	305
3 3/8	30.2	38.5	9 3/4	252	321
3 1/2	**32.5**	**41.4**	**10**	**266**	**337**
3 5/8	34.9	44.4	10 1/4	278	355
3 3/4	37.3	47.5	10 1/2	292	372
3 7/8	39.9	50.8	10 3/4	306	390
4	**42.5**	**54.1**	**11**	**321**	**409**
4 1/8	45.2	57.5	11 1/4	336	427
4 1/4	48.0	61.1	11 1/2	351	447
4 3/8	50.8	64.7	11 3/4	366	466
4 1/2	**53.8**	**68.4**	**12**	**382**	**486**
4 5/8	56.8	72.3	13	447	570
4 3/4	60.0	76.3	14	515	661
4 7/8	63.1	80.3	15	596	758

FLAT BAR.

Wide	1/4 Thick.	3/8 Thick.	1/2 Thick.	5/8 Thick.	3/4 Thick.
ins.	lbs.	lbs.	lbs.	lbs.	lbs.
1	**0.8**	**1.3**	**1.7**	**2.1**	**2.5**
1 1/4	1.1	1.6	2.1	2.6	3.2
1 1/2	1.3	1.9	2.5	3.2	3.8
1 3/4	1.5	2.2	3.0	3.7	4.4
2	**1.7**	**2.5**	**3.4**	**4.2**	**5.1**
2 1/4	1.9	2.9	3.8	4.8	5.7
2 1/2	2.1	3.2	4.2	5.3	6.3
2 3/4	2.3	3.5	4.6	5.8	7.0
3	**2.5**	**3.8**	**5.1**	**6.3**	**7.6**
3 1/4	2.7	4.1	5.5	6.9	8,2
3 1/2	3.0	4.4	5.9	7.4	8.9
3 3/4	3.2	4.8	6.3	7.9	9.5
4	**3.4**	**5.1**	**6.8**	**8.4**	**10.1**
4 1/4	3.6	5.4	7.2	9.0	10.8
4 1/2	3.8	5.7	7.6	9.5	11.4
4 3/4	4.0	6.0	8.0	10.0	12.0
5	**4.2**	**6.3**	**8.4**	**10.6**	**12.7**
5 1/4	4.4	6.7	8.9	11.1	13.3
5 1/2	4.6	7.0	9.3	11.6	13.9
5 3/4	4.9	7.3	9.7	12.1	14.6
6	**5.1**	**7.6**	**10.1**	**12.7**	**15.2**

SHEET METALS.—Foot Sup.

Wire gauge	Thickness. ins.	Thickness. dec.	Iron.	Copper.	Brass	Lead.
No.	ins.	dec.	lbs.	lbs.	lbs.	lbs.
	1		40	45.20	43.2	60.
	7-8		35	39.55	37.8	52.5
	3-4	.75	30	33.90	32.4	45.
	5-8		25	28.25	27.0	37.5
	1-2	.50	20	22.60	21.6	30.
	7-16		17.5	19.77	18.9	26.25
	3-8		15.0	16.95	16.2	22.5
1	5-16	.30	12.5	14. 5	13.8	18.75
2		.29	12.2	13. 8	13.3	18.3
4	1-4	.25	10.0	11. 3	10.8	15.
6		.21	8.3	9. 4	8.9	12.45
7	3-16	.19	7.5	8. 5	8.1	11.25
8		.17	6.6	7. 4	7.1	9.90
10		.13	5.5	6. 2	5.9	8.25
11	1-8	.12	5.0	5. 6	5.4	7.50
12		.11	4.3	4. 8	4.6	6.65
14		.08	3.2	3. 6	3.4	4.80
16	1-16	.06	2.5	2. 8	2.7	3.75
18		.05	1.9	2. 1	2.0	2.85
20		.03	1.5	1. 7	1.7	2.25
22	1-32		1 2	1. 3	1.4	1.80

WEIGHT OF CAST IRON BALLS.

Size.	Weight.	Size.	Weight.
ins.	lbs.	ins.	lbs.
1	0.136	6	29.50
2	1.10	7	47.00
3	3.70	8	70.00
4	8.70	9	100.00
5	17.10	10	137.00

SUSPENSION BRIDGES.—TABLE 22

LENGTH AND TENSION OF CHAINS.

With Sines and Cosines of the Angles of Direction for given Deflections.

Rule.—For Tension—Multiply the total weight to be suspended by the factor opposite the deflection or versed sine of the Chains; the product is the total tension at the middle, or point of suspension, as may be required. The use of the other columns are obvious.

Angle at Point of Suspension.	Versed Sine or Deflection.	Length of Chain, Chord line being Unity.	Tension at the Middle Weight suspended being Unity.	Tension at each point of Suspension. Weight suspended being Unity.	Sine of the Angle at Point of Suspension.	Cosine of Angle at Point of Suspension.
5..43	1-40th	..	4.995	5.200	0.0996	0.9950
11..19	1-20th	..	2.485	2.536	0.1962	0.9805
13..52	1-16.28	1.012	2.003	2.080	0.2396	0.9708
14..55	1-15th	1.015	1.877	1.943	0.2574	0.9663
15..57	1-14th	1.018	1.753	1.823	0.2747	0.9615
17..06	1-13th	1.020	1.625	1.700	0.2940	0.9558
18..33	1-12th	1.0246	1.490	1.572	0.3181	0.9480
19..59	1-11th	1.0288	1.373	1.463	0.3417	0.9398
21..48	1-10th	1.0349	1.252	1.349	0.3714	0.9285

GENERAL RULES FOR CATENARY CURVES.

To find angle of direction (x) of curve at point of suspension, when the chord line and versed sine are given?

$$\text{sine of } x = \frac{2 \text{ v. sine}}{\sqrt{(2 \text{ v. sine}^2 + \text{semichord}^2)}}$$

To find the tension at each point of suspension (T) when the angle of direction (x) at such points is given?

$$T = \frac{\text{Total weight suspended.}}{2 \text{ sine } x.}$$

To find the tension at the lowest point of the curve (t) when the angle of direction (x) at the point of suspension is given?

$$t = \frac{\tfrac{1}{2} \text{ the weight suspended} \times \text{cosine } x}{\text{sine } x.}$$

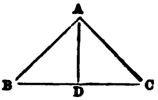
NOTE.—For an easy rule, although not precisely accurate, take—

$$t = \frac{\text{chord} \times \text{weight}}{8 \text{ v. sine}}$$

Horizontal pull on the points of suspension $=$ T$\times$ *cosine* x; therefore if chains are unbalanced, this will represent the tendency to upset the towers; and if the chains pass back at an unequal angle, the difference of the cosines of the angles of direction is the measure of resistance on each.

Vertical pressure on the points of suspension $=$ T$\times$sine x. This pressure is additive in any case, for both sides of the point for the tension on the backstay must balance the main chains, the difference of pressure on each side is therefore only as the sine of the angle x.—*(Drewry, on S. Bridges.)*

ROOFS AND LOCK GATES.—TABLE 22a.



TENSION OR THRUST OF ROOFS, &c.

TABLE of the Proportional Tension of B C, the angle B A C, and the versed sine A D being given; taking the weight on A B and A C as unity for the tension, and the length B C as unity for the length of A D.

Subtended Angle. B A C	Pitch or V. Sine. A D	Tension. B C	Subtended Angle. B A C	Pitch or V. Sine. A D	Tension. B C	Subtended Angle. B A C	Pitch or V. Sine. A D	Tension. B C
Deg. Min.	Base=1.0	Wt =1.00	Deg. Min.	Base=1.0	Wt.=1.00	Deg. Min.	Base=1.0	Wt.=1.00
179.30	.002	114.9	170.00	.043	5.76			
179.00	.004	57.47	169.30	.046	5.49	156.	.106	2.46
178.30	.006	38.17	169.00	.048	5.24	155.	.110	3.36
178.00	.008	28.65	168.30	.050	5.02	154.	.115	2.28
177.30	.011	22.93	168.00	.052	4.81	153.	.120	2.20
177.00	.013	19.12	167.30	.054	4.62	152.	.124	2.13
176.30	.015	16.39	167.00	.057	4.45	151.	.129	2.06
176.00	.017	14.35	166.30	.059	4.28	150.	.134	2.00
175.30	.019	12.75	166.00	.061	4.13	145.	.157	1.74
175.00	.022	11.48	165.30	.063	3.99	140.	.182	1.55
174.30	.024	10.44	165.	.065	3.86	135.	.207	1.41
174.00	.026	9.57	164.	.070	3.63	130.	.233	1.30
173.30	.028	8.83	163.	.074	3.42	125.	.260	1.22
173.00	.030	8.20	162.	.079	3.23	120.	.288	1.15
172.30	.032	7.66	161.	.083	3.07	115.	.318	1.10
172.00	.035	7.18	160.	.088	2.92	110.	.350	1.06
171.30	.037	6.76	159.	.092	2.79	105.	.383	1.03
171.00	.039	6.39	158.	.097	2.67	100.	.419	1.01
170.30	.041	6.06	157.	.101	2.56	90.	.500	1.00

STRAIN AND DIMENSIONS OF LOCK GATES.

TABLE of Transverse Strain from Pressure of Water, upon 3 feet depth of Surface, at the stated heads; with the dimensions of square oak timber necessary to bear three times such strain; the Gates being placed at an angle of 19°.25′.

Length of Gate.	6 Feet.		8 Feet.		10 Feet.		12 Feet.		14 Feet.		16 Feet.		18 Feet.		20 Feet.	
	Strn. on 3 feet dpth. of surface.	Size to bear three times' strain	Strn. on 3 feet dpth. of surface	Size to bear three times' strain	Strn. on 3 feet dpth. of surface	Size to bear three times' strain	Strn. on 3 feet dpth of surface	Size to bear three times' strain	Strn on 3 feet dpth of surface	Size to bear three times' strain	Strn. on 3 feet dpth of surface	Size to bear three times' strain	Strn. on 3 feet dpth of surface	Size to bear three times' strain	Strn on 3 feet dpth of surface.	Size to bear three times' strain.
Feet	Tns.	Inches	Tns	Inches	Tns.	Inches	Tns	Inches	Tns.	Inches	Tns.	Inches	Tns.	Inches	Tns.	Inches
6	1.9	5.49	2.5	6.05	3.2	6.05	3.8	6.92	4.5	7.29	5.1	7.62	5.7	7.93	6.4	8.21
7	2.2	6.09	2.9	6.70	3.7	7.22	4.4	7.67	5.2	8.07	5.9	8.45	6.7	8.78	7.4	9.10
8	2.5	6.66	3.4	7.32	4.2	7.89	5.1	8.39	5.9	8.83	6.8	9.23	7.6	9.60	8.5	9.94
9	2.8	7.20	3.8	7.92	4.8	8.54	5.7	9.07	6.7	9.55	7.6	9.98	8.6	10.38	9.6	10.75
10	3.2	7.72	4.2	8.50	5.3	9.16	6.4	9.73	7.4	10.24	8.5	10.71	9.6	11.14	10.6	11.54
11	3.5	8.23	4.6	9.06	5.8	9.76	7.0	10.37	8.2	10.92	9.3	11.41	10.5	11.87	11.7	12.30
12	3.8	8.72	5.1	9.60	6.4	10.34	7.6	10.98	8.9	11.57	10.2	12.10	11.5	12.58	12.8	13.03
13	4.1	9.20	5.5	10.12	6.9	10.90	8.3	11.59	9.7	12.20	11.0	12.76	12.4	13.27	13.8	13.74
14	4.4	9.67	5.9	10.64	7.4	11.46	8.9	12.18	10.4	12.82	11.9	13.40	13.4	13.94	14.9	14.44
15	4.8	10.12	6.4	11.14	8.0	12.00	9.6	12.75	11.2	13.42	12.8	14.03	14.4	14.55	16.0	15.12
16	5.1	10.56	6.8	11.63	8.5	12.53	10.2	13.31	11.9	14.01	13.6	14.65	15.3	15.24	17.0	15.78
17	5.4	11.00	7.2	12.11	9.0	13.05	10.8	13.86	12.6	14.60	14.5	15.26	16.3	15.86	18.1	16.43
18	5.7	11.43	7.6	12.58	9.6	13.55	11.5	14.40	13.4	15.16	15.3	15.85	17.2	16.48	19.2	17.07
19	6.0	11.85	8.1	13.04	10.1	14.04	12.1	14.93	14.1	15.72	16.2	16.43	18.2	17.09	20.2	17.70
20	6.4	12.26	8.5	13.49	10.6	14.54	12.8	15.45	14.9	16.26	17.0	17.00	19.2	17.68	21.3	18.31

CAST IRON BEAMS.—TABLE 23

TABLE OF SAFE LOAD,

IF EQUALLY DISTRIBUTED, EXPRESSED IN CWTS.

For Beams 6 to 16 Inches deep.

Rule.—Multiply the area which a proposed beam has to support, by the weight of the floor or bridge, and the greatest load, due to such area, all in cwts.; find the nearest corresponding number in the table, having the required depth and length, and the proper dimensions of the bottom Flange will be found at top of the column. The tables also give the safe weight to be borne by beams of any of the stated dimensions.

Note.—Floors should generally be reckoned to carry 2.5 cwts. per foot superficial, including their own weight.
Road Bridges „ „ „ 5.0 cwts. „ „
Railway Bridges „ „ „ 10.0 cwts. „ „
but for railway girders of cast iron, beyond 18 feet span, only half the tabular numbers should be used.

Beam 6 inches deep.						Beam 8 inches deep.				
Dimensions of bottom Flange in inches.	4×1	5×1	6×1	8×1¼	9×1¼	4×1	5×1	6×1	8×1¼	9×1¼
Length, feet.	Cwts.	Cwts.	Cwts.	Cwts	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
5	133	166	200	333	391	177	222	266	444	521
6	111	139	166	277	326	148	185	222	370	435
8	83	104	125	208	244	111	139	166	277	325
10	66	83	100	166	195	89	111	133	222	260
12	55	69	83	138	163	74	92	111	185	217
14	47	59	71	119	140	63	79	95	159	187
16	41	52	62	104	122	55	69	83	138	163
18	37	46	55	92	108	49	62	74	123	144

Beam 10 inches deep.						Beam 12 inches deep.				
Dimensions of bottom Flange in inches.	5×1	6×1	8×1¼	9×1¼	10×1¼	6×1	8×1¼	9×1¼	10×1¼	11×1½
Length, feet.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
6	231	277	463	521	578	333	555	625	694	916
8	173	208	346	391	434	250	416	469	521	688
10	139	166	278	313	347	200	333	375	417	550
12	115	139	230	260	289	166	278	312	347	458
14	99	119	198	223	248	109	238	268	298	393
16	86	104	172	195	217	125	208	234	261	344
18	77	93	154	173	193	111	185	208	232	306
20	69	83	138	156	173	100	166	187	209	275

Beam 14 inches deep.						Beam 16 inches deep.				
Dimensions of bottom Flange in inches.	8×1¼	9×1¼	10×1¼	11×1½	12×1½	8×1¼	9×1¼	10×1¼	11×1½	12×1½
Length, feet.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts
8	486	547	607	802	875	555	625	694	916	1000
10	389	438	486	642	700	444	500	555	733	800
12	324	365	405	535	584	370	417	463	611	667
14	278	313	347	459	501	317	357	397	524	572
16	243	274	304	401	437	278	313	347	458	500
18	216	244	270	357	389	246	278	309	407	444
20	195	219	243	321	350	222	250	278	366	400
22	177	199	221	291	318	202	227	250	333	364

CAST IRON BEAMS.—TABLE 23

TABLE OF SAFE LOAD.

For Beams 18 to 30 inches deep.

Dimensions of bottom Flange in inches.	Beam 18 inches deep.					Beam 21 inches deep.				
	9×1½	10×1½	12×1½	13×1½	14×1½	10×1½	12×1½	14×1½	15×1½	16×1½
Length, feet.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
10	562	625	900	975	1050	875	1050	1225	1312	1400
12	469	524	750	813	875	729	875	1021	1094	1167
14	402	446	643	696	750	625	750	875	937	1000
16	351	390	562	609	656	546	656	766	820	875
18	312	347	500	542	583	486	583	681	729	778
20	281	312	450	487	525	437	525	613	656	700
22	256	284	409	443	477	398	477	557	596	637
24	234	261	375	406	437	364	437	510	547	583

Beam 24 inches deep.

Dimensions of bottom Flange in inches.	10×1½	12×1½	14×1½	15×1½	16×1½	16×2	17×1½	17×2	18×1½	18×2
Length, feet.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
12	833	1000	1166	1250	1333	1778	1416	1819	1500	2000
14	714	857	1000	1071	1143	1524	1214	1560	1286	1714
16	623	750	875	937	960	1333	1062	1365	1125	1500
18	555	666	777	833	889	1185	944	1213	1000	1333
20	500	600	700	750	800	1067	849	1092	900	1200
22	454	545	636	682	727	970	772	992	818	1091
24	416	500	583	625	666	889	708	910	750	1000
26	384	461	538	577	615	836	656	840	692	923
28	357	428	500	535	571	762	607	780	643	857
30	333	400	467	500	534	711	566	728	600	800

Beam 27 inches deep.

Dimensions of bottom Flange in inches.	12×1½	14×1½	14×2	15×1½	15×2	16×1½	16×2	17×1½	17×2	18×2
Length, feet.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
14	964	1125	1500	1205	1607	1286	1714	1366	1821	1928
18	740	863	1166	937	1249	1000	1333	1062	1416	1500
22	613	715	954	707	1022	818	1091	869	1159	1227
24	562	656	875	703	937	750	1000	797	1062	1125
28	482	562	750	603	803	643	857	683	911	964
30	450	525	700	562	750	600	800	637	850	900
32	422	492	656	527	702	562	750	598	797	843
34	397	463	618	496	661	530	706	562	750	794
36	375	437	583	469	625	500	666	531	708	750
40	337	388	525	421	563	450	600	478	638	675

Beam 30 inches deep.

Dimensions of bottom Flange in inches.	14×1½	14×2	15×1½	15×2	16×1½	16×2	18×2	20×2	22×2	24×2
Length, feet.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
18	972	1296	1041	1389	1111	1481	1666	1852	2038	2222
22	795	1060	852	1136	909	1212	1363	1515	1667	1818
24	714	952	781	1041	832	1111	1250	1388	1526	1664
28	612	816	669	892	714	952	1071	1190	1309	1428
30	571	761	625	833	679	889	1000	1111	1245	1358
32	536	715	586	780	624	833	937	1040	1144	1248
34	514	685	551	734	589	783	882	979	1080	1178
36	486	648	521	695	555	740	833	927	1019	1110
40	428	570	469	625	500	666	750	833	917	1000
44	397	529	426	568	454	606	681	757	833	908

MARINE SURVEYING.—Table 24

ANGLES OF THE POINTS OF THE COMPASS WITH THE MERIDIAN.

Variation of magnetic needle 1850, latitude 51° =
Dip. " " " " =

North.	South.	Points.	Deg. Min.	North.	South.
		Add for ¼	2..48..45		
		" ½	5..37..30		
		" ¾	8..26..15		
N. by W.	S. by W.	1	11..15	N. by E.	S. by E.
N.N.W.	S.S.W.	2	22..30	N.N.E.	S.S.E.
N.W. by N.	S.W. by S.	3	33..45	N.E. by N.	S.E. by S.
N.W.	S.W.	4	45..00	N.E.	S.E.
N.W. by W.	S.W. by W.	5	56..15	N.E. by E.	S.E. by E.
W.N.W.	W.S.W.	6	67..30	E.N.E.	E.S.E.
W. by N.	W. by S.	7	78..45	E. by N.	E. by S.
West	West	8	90..00	East	East

MILES IN A DEGREE OF LONGITUDE AT EVERY DEGREE OF LATITUDE.

Degs. Lat.	Miles.	Degs. Lat.	Miles.	Degs. Lat.	Miles.	Degs. Lat.	Miles.	Degs. Lat.	Miles.	Degs. Lat.	Miles.
1	59.99	16	57.67	31	51.43	46	41.68	61	29.09	76	14.52
2	59.96	17	57.38	32	50.88	47	40.92	62	28.17	77	13.50
3	59.92	18	57.06	33	50.32	48	40.15	63	27.24	78	12.47
4	59.85	19	56.73	34	49.74	49	39.36	64	26.30	79	11.45
5	59.77	20	56.38	35	49.15	50	38.57	65	25.36	80	10.42
6	59.67	21	56.01	36	48.54	51	37.76	66	24.40	81	9.39
7	59.55	22	55.63	37	47.92	52	36.94	67	23.44	82	8.35
8	59.42	23	55.23	38	47.28	53	36.11	68	22.48	83	7.31
9	59.26	24	54.81	39	46.63	54	35.27	69	21.50	84	6.27
10	59.08	25	54.38	40	45.96	55	34.41	70	20.52	85	5.23
11	58.89	26	53.93	41	45.28	56	33.55	71	19.53	86	4.19
12	58.68	27	53.46	42	44.59	57	32.68	72	18.54	87	3.14
13	58.46	28	52.97	43	43.88	58	31.80	73	17.54	88	2.09
14	58.22	29	52.47	44	43.16	59	30.90	74	16.54	89	1.05
15	57.95	30	51.96	45	42.43	60	30.00	75	15.53	90	0.00

24856 miles	=	mean circumference of Earth.
7921 "	=	" diameter of Earth.
20921180 feet	=	radius of the Equator.
20853180 "	=	polar semi-axis.
60756.6	=	length of Geogr. or nautical mile.
1.15068 to 1	=	ratio of nautical to English mile.
39.01326 ins.	=	length of pendulum at the Equator.
39.11820 "	=	" at latitude 45.
39.1393 ins.	=	length of pendulum at London.
39.1555 "	=	" " Edinburgh.
32.1948 feet	=	force of gravity at London, in feet per second.
32.2041 "	=	" " Edinburgh " "
365.242245 days	=	tropical year.

MARINE SURVEYING.—Table 24 a, b, c.

Table 24a.
VELOCITY AND PRESSURE OF THE WIND.

Feet ℔ Min.	Miles ℔ Hour.	Force in lbs. on Sq. Foot.	Description.
88	1	.005	Hardly perceptible.
352	4	.079	Gentle wind and breezes.
440	5	0.123	
880	10	0.492	Good breeze.
1320	15	1.107	
1760	20	1.970	Brisk gale.
2640	30	4.429	High winds.
3080	35	6.027	
3520	40	7.870	Very high.
3960	45	9.960	
4400	50	12.300	Storm.
5280	60	16.710	Great storm.
7040	80	31.490	Hurricane.
8800	100	49.200	

TIDES occur twice in every 24 hours and 50½ minutes. When a place is on the same side of the Equator as the moon, the Tide which is produced, while the moon is *above* the horizon, is greater than while the moon is *under* the horizon of the place. When a place is on the opposite side of the Equator to the moon, the effect is reversed. In Midsummer, the afternoon Tides are higher than the morning Tides. In winter the morning Tides are highest.

Table 24b.
For finding the Height of Tide at any period after High Water.

Time from High Water. Hours.	Min.	Multiplier.
0 ..	00	1.000
0 ..	30	.975
1 ..	00	.916
1 ..	30	.841
2 ..	00	.741
2 ..	30	.625
3 ..	00	.500
3 ..	30	.375
4 ..	00	.258
4 ..	30	.158
5 ..	00	.083
5 ..	30	.025

Rule.—Multiply the range of Tide for the day by the Factor opposite the hour at which the height is required.

Example.—The total rise of Tide at Limehouse, on the 12th of April, was 20.4 feet; High Water made at 2 p.m: what was the height of Tide at 4 p.m.?

20.4×74=15.11 feet.

Table 24 c.
SHOWING THE LENGTH IN FEET OF ONE MINUTE OF LONGITUDE AND LATITUDE,
Being One Nautic Mile.

Note.—To obtain the number of miles in a degree, at any latitude or longitude, multiply the tabular numbers by 60, and divide by 5280; thus, at the Equator, the length of a degree is 69.15 miles.

Latitude.	Minute of Longitude.	Minute of Latitude.	Latitude.	Minute of Longitude.	Minute of Latitude.	Latitude.	Minute of Longitude.	Minute of Latitude.
Deg.	Feet.	Feet.	Deg.	Feet.	Feet.	Deg.	Feet.	Feet.
0	6085.2	6085.20	35	4990.2	6105.0	53	3670.2	6124.8
2	6081.6		36	4920.0		54	3585.0	
4	6070.2		37	4866.0		55	3498.0	
6	6052.2		38	4801.2		56	3410.4	
8	6026.4		39	4735.2		57	3322.2	
10	5993.4		40	4668.0		58	3232.2	
12	5953.2	6087.78	41	4599.0	6111.6	59	3141.6	6130.1
14	4905.8		42	4528.8		60	3050.4	
16	5851.2		43	4457.4		61	2958.0	
18	5789.4		44	4384.2		62	2864.4	
20	5721.6		45	4309.8		63	2770.2	
22	5645.4		46	4234.2		64	2675.8	
24	5562.0	6095.22	47	4157.4	6118.2	65	2578.8	6135.6
26	5472.6		48	4079.4		66	2482.2	
28	5377.2		49	3999.6		67	2384.4	
30	5274.0		50	3919.2		68	2286.0	
32	5165.4		51	3837.0		69	2187.0	
34	5050.2		52	3754.2		70	2087.4	

MOUNTAIN BAROMETER.—TABLE 25

TABLE B.
Difference of Temperature.

Diff. of Temp.	Correc-tions.	Diff. of Temp.	Correc-tions.
Cent. degs.	feet.	Cent. degs.	feet.
0.5	2.46	10.5	50.69
1.0	4.92	11.0	53.15
1.5	7.21	11.5	55.44
2.0	9.51	12.0	57.74
2.5	11.97	12.5	60.20
3.0	14.43	13.0	62.66
3.5	16.89	13.5	65.12
4.0	19.35	14.0	67.58
4.5	21.81	14.5	70.04
5.0	24.27	15.0	72.50
5.5	26.57	15.5	74.80
6.0	28.87	16.0	77.10
6.5	31.33	16.5	79.56
7.0	33.79	17.0	82.02
7.5	36.25	17.5	84.48
8.0	38.71	18.0	86.94
8.5	41.00	18.5	89.40
9.0	43.30	19.0	91.86
9.5	45.76	19.5	94.32
10.0	48.22	20.0	96.78

Table A can be applied to any barometer, deducting the number for the temperature from the observations for heights.

Table B gives the amount to be *deducted* from the height, according to the difference of the attached thermometers—or to be *added*, if the upper station should be warmer than the lower. For correction due to expansion of air, &c. see "Rules."

Table C gives the amount to be added for gravity & centrifugal force.

TABLE A.
For reduction to Freezing Point.

Temp.	Corrections for the Barometer at			
	27 Inches.	28 Inches.	29 Inches.	30 Inches.
Fah. degs.	inch.	inch.	inch.	inch.
32	.0086	.0088	.0091	.0094
34	.0134	.0138	.0143	.0148
36	.0183	.0188	.0194	.0201
38	.0231	.0238	.0246	.0255
40	.0279	.0288	.0298	.0309
42	.0327	.0338	.0350	.0362
44	.0375	.0388	.0402	.0416
46	.0423	.0438	.0454	.0470
48	.0471	.0488	.0506	0523
50	.0519	.0538	.0558	.0577
52	.0568	.0588	.0609	.0630
54	.0616	.0638	.0661	.0684
56	.0664	.0688	.0713	.0738
58	.0712	.0738	.0765	.0791
60	.0760	.0788	.0817	.0845
62	.0809	.0838	.0868	.0898
64	.0857	.0888	.0920	.0951
66	.0906	.0938	.0971	.1005
68	.0954	.0988	.1023	.1058
70	.1000	.1037	.1075	.1112
72	.1049	.1087	.1126	.1165
74	.1097	.1137	.1178	.1218
76	.1146	.1187	.1229	.1272
78	.1194	.1237	.1281	.1325
80	.1241	.1286	.1332	.1378
82	.1289	.1336	.1384	.1432
84	.1338	.1386	.1435	.1485
86	.1385	.1435	.1486	.1538
88	.1433	.1485	.1538	.1591
90	.1482	.1535	.1589	.1644

TABLE C.
Gravity and Centrifugal force.
CORRECTIONS TO BE ADDED.

Latitude.	to 10°	15°	20°	25°	30°	35°	40°	45°	50°	55°
Approx. height. feet.	feet.	feet	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
600	3.9	3.3	3.3	3.3	2.6	2.6	1.9	1.9	1.9	1.3
1300	7.9	7.2	6.5	6.5	5.9	5.6	4.6	3.9	3 3	2.6
2000	11.1	10.5	9.8	9.2	8.5	7.9	6.5	5.9	5.2	3.9
2600	14.7	14.1	14.0	12.4	11.5	10.2	6.2	7.8	6.5	5.5
3300	20.1	17.5	17.3	15.7	14.1	12.4	11.1	10.1	8.5	7.2
4000	22.9	20.9	19.7	19.0	16.7	15.1	13.7	11.8	10.1	8.5
4600	26.9	24.9	23.3	22.0	20.0	17.7	15.7	13.7	11.8	9.8
5300	30.2	28.9	26.9	24.9	22.9	20.3	18.3	15.7	14.0	11.1
5900	34.1	32.1	30.8	38.2	26.2	22.9	20.6	17.7	15.1	12.4
6600	37.7	36.1	34.1	31.5	28.9	25.7	22.9	19.7	17.3	13.7

Table D.

TABLE OF THE ELASTIC FORCE OF AQUEOUS VAPOUR,

WITH THE WEIGHT, IN GRAINS TROY, OF A CUBIC FOOT,

At the following Temperatures of the Dew Point, in Degrees Fahrenheit.

Temp. of Dew Point.	Force of Aqueous Vapour.	Weight in Grns. Troy of Cub. Ft. of Vapour.	Temp. of Dew Point.	Force of Aqueous Vapour.	Weight in Grns. Troy of Cub. Ft. of Vapour.	Temp. of Dew Point.	Force of Aqueous Vapour.	Weight in Grns. Troy of Cub. Ft. of Vapour.
Fah.	Inches.	Grains.	Fah.	Inches.	Grains.	Fah.	Inches.	Grains.
5°	.074	0.93	31°	0.192	2.29	51°	.386	4.42
10	.089	1.11	32	.199	2.37	52	.400	4.56
12	.096	1.19	33	.207	2.45	53	.414	4.71
14	.104	1.28	34	.214	2.53	54	.428	4.86
15	.108	1.32	35	.222	2.62	55	.442	5.02
16	.112	1.37	36	.230	2.71	56	.458	5.18
17	.116	1.41	37	.238	2.80	57	.473	5.34
18	.120	1.47	38	.246	2.89	58	.489	5.51
19	.125	1.52	39	.255	2.99	59	.506	5.69
20	.129	1.58	40	.264	3.09	60	.523	5.87
21	.134	1.63	41	.274	3.19	62	.559	6.25
22	.139	1.69	42	.283	3.30	64	.597	6.65
23	.144	1.75	43	.293	3.41	66	.638	7.08
24	.150	1.81	44	.304	3.52	68	.681	7.53
25	.155	1.87	45	.315	3.64	70	.727	8.00
26	.161	1.93	46	.326	3.76	72	.776	8.50
27	.167	2.00	47	.337	3.88	74	.827	9.04
28	.173	2.07	48	.349	4.01	76	.882	9.60
29	.179	2.14	49	.361	4.14	78	.940	10.19
30	.186	2.21	50	.373	4.28	80	1.001	10.81

Table F.

CORRECTIONS,

To be added to the Mercurial Column for Capillary Attraction.

Diam. of Tube.	Correction	Diam. of Tube.	Correction
Inch.	Inch.	Inch.	Inch.
.10	.140	.30	.029
.12	.113	.35	.021
.14	.094	.40	.015
.16	.079	.45	.011
.18	.068	.50	.008
.20	.058	.55	.006
.25	.041	.60	.004

Note.—This correction is practically unnecessary, excepting for scientific reduction of observations.

Mountain Barometers, when varying in size, when used for simultaneous observations, should have their comparative errors determined by inspection.

Rule for Table D.

This Table shows the amount to be deducted from the mercurial column, to obtain the true pressure of dry air; the dew point having been previously computed by Table E, from observations of the ordinary dry and wet bulb thermometer.

Example.

The Barometer stands at 29.275
When the dew-point, by calculation,
is 16.2°, the pressure = ... .117

True pressure of air = 29.158

Table E.

DRY AND WET BULB THERMOMETERS.

Factors for deducing the Dew Point from the Temperature of Evaporation.

Readings of the Dry Bulb Thermometer. Fah.	Factor.
Between 28° and 29°	5.7
„ 29 „ 30	5.0
„ 30 „ 31	4.6
„ 31 „ 32	3.6
„ 32 „ 33	3.1
„ 33 „ 34	2.8
„ 34 „ 35	2.6
„ 35 „ 40	2.4
„ 40 „ 45	2.3
„ 45 „ 50	2.2
„ 50 „ 55	2.1
„ 55 „ 60	1.9
„ 60 „ 70	1.8
„ 70 „ 80	1.7

Rule for Table E.

Multiply the difference between the two thermometers by the *factor* corresponding to the temperature of the dry bulb thermometer; the product, subtracted from the latter, gives the temperature of the dew point.

Example.

Dry bulb thermometer = 66°
Wet bulb thermometer = 57

Difference...... = 9
Factor for 66° .. = 1.8

Product.... = 16.2

66°——16.2° = 49.8° temp. of dew point.

AREA AND CIRCUMFERENCE OF CIRCLES.

Diameters 1 to 43.

The Square Root of any Area is the side of an equivalent Square.

Diam.	Area.	Circum.	Diam.	Area.	Circum.	Diam.	Area.	Circum.
			13.25	137.88	41.62	28.25	626.79	88.75
			13.5	143.14	42.41	28.5	637.94	89.53
.1	0.007	.31	13.75	148.49	43.19	28.75	649.18	90.32
.2	0.031	.62	14.	153.94	43.98	29.	660.51	91.10
.3	0.070	.94	14.25	159.48	44.77	29.25	671.95	91.89
.4	0.125	1.26	14.5	165.13	45.55	29.5	683.49	92.67
.5	0.196	1.57	14.75	170.87	46.34	29.75	695.12	93.46
.6	0.282	1.88	15.	176.71	47.12	30.	706.85	94.24
.7	0.384	2.20	15.25	182.65	47.90	30.25	718.68	95.03
.8	0.502	2.51	15.5	188.69	48.69	30.5	730.61	95.81
.9	0.636	2.82	15.75	194.82	49.48	30.75	742.64	96.60
1.00	.7854	3.1416	**16.**	201.06	50.26	**31.**	754.76	97.38
1.25	1.22	3.92	16.25	207.39	51.05	31.25	766.99	98.17
1.5	1.76	4.71	16.5	213.82	51.83	31.5	779.31	98.96
1.75	2.40	5.49	16.75	220.35	52.62	31.75	791.73	99.74
2.	3.14	6.28	17.	226.98	53.40	32.	804.24	100.53
2.25	3.97	7.06	17.25	233.70	54.19	32.25	816.86	101.31
2.5	4.90	7.85	17.5	240.52	54.97	32.5	829.57	102.10
2.75	5.93	8.63	17.75	247.44	55.76	32.75	842.38	102.88
3.	7.06	9.42	**18.**	264.47	56.54	**33.**	855.29	103.67
3.25	8.29	10.21	18.25	266.58	57.33	33.25	868.30	104.45
3.5	9.62	10.99	18.5	268.80	58.11	33.5	881.41	105.24
3.75	11.04	11.78	18.75	276.11	58.90	33.75	894.61	106.02
4.	12.56	12.56	19.	283.53	59.69	34.	907.92	106.81
4.25	14.18	13.35	19.25	291.04	60.47	34.25	921.32	107.59
4.5	15.90	14.14	19.5	298.64	61.26	34.5	934.82	108.38
4.75	17.72	14.92	19.75	306.35	62.04	34.75	948.41	109.17
5.	19.63	15.70	**20.**	314.16	62.83	**35.**	962.11	109.95
5.25	21.65	16.49	20.25	322.06	63.61	35.25	975.90	110.74
5.5	23.76	17.28	20.5	330.06	64.40	35.5	989.79	111.52
5.75	25.97	18.06	20.75	338.16	65.18	35.75	1003.78	112.31
6.	28.27	18.85	21.	346.36	65.97	36.	1017.87	113.09
6.25	30.68	19.63	21.25	354.65	66.75	36.25	1032.06	113.88
6.5	33.18	20.42	21.5	363.05	67.54	36.5	1046.34	114.66
6.75	35.78	21.20	21.75	371.54	68.32	36.75	1060.73	115.45
7.	38.48	21.99	**22.**	380.13	69.11	**37.**	1075.21	116.23
7.25	41.28	22.77	22.25	388.82	69.90	37.25	1089.79	117.02
7.5	44.17	23.56	22.5	397.60	70.68	37.5	1104.46	117.80
7.75	47.17	24.34	22.75	406.49	71.47	37.75	1119.24	118.59
8.	50.26	25.13	23.	415.47	72.25	38.	1134.11	119.38
8.25	53.45	25.92	23.25	424.55	73.04	38.25	1149.08	120.16
8.5	56.74	26.70	23.5	433.73	73.82	38.5	1164.15	120.95
8.75	60.13	27.49	23.75	443.01	74.61	38.75	1179.32	121.73
9.	63.62	28.27	**24.**	452.39	75.39	**39.**	1194.59	122.52
9.25	67.20	29.06	24.25	461.86	76.18	39.25	1209.95	123.30
9.5	70.88	29.84	24.5	471.43	76.96	39.5	1225.41	124.09
9.75	74.66	30.63	24.75	481.10	77.75	39.75	1240.97	124.87
10.	78.54	31.42	25.	490.87	78.53	40.	1256.63	125.66
10.25	82.52	32.20	25.25	500.74	79.32	40.25	1272.39	126.44
10.5	86.59	32.98	25.5	510.70	80.11	40.5	1288.24	127.23
10.75	90.76	33.77	25.75	520.76	80.89	40.75	1304.20	128.01
11.	95.03	34.55	**26.**	530.93	81.68	**41.**	1320.25	128.80
11.25	99.40	35.34	26.25	541.18	82.46	41.25	1336.40	129.59
11.5	103.87	36.13	26.5	551.54	83.25	41.5	1352.65	130.37
11.75	108.43	36.91	26.75	562.00	84.03	41.75	1368.99	131.16
12.	113.09	37.69	27.	572.55	84.82	42.	1385.44	131.94
12.25	117.86	38.48	27.25	583.20	85.60	42.25	1401.98	132.73
12.5	122.72	39.27	27.5	593.95	86.39	42.5	1418.62	133.51
12.75	127.67	40.05	27.75	604.80	87.17	42.75	1435.36	134.30
13.	132.73	40.84	**28.**	615.75	87.96	**43.**	1452.20	135.08

CIRCLES.—TABLE 26

AREA AND CIRCUMFERENCE OF CIRCLES.

Diameters 43.25 to 100.

The Square Root of any Area is the side of an equivalent Square.

Diam.	Area.	Circum.	Diam.	Area.	Circum.	Diam.	Area.	Circum.
43.25	1469.13	135.87	58.25	2664.90	182.99	73.25	4214.10	230.12
43.5	1486.16	136.65	58.5	2687.82	183.78	73.5	4242.91	230.90
43.75	1503.30	137.44	58.75	2710.85	184.56	73.75	4271.82	231.69
44.	1520.53	138.23	59.	2733.97	185.35	74.	4300.84	232.47
44.25	1537.85	139.01	59.25	2757.18	186.13	74.25	4329.94	233.26
44.5	1556.28	139.80	59.5	2780.50	186.92	74.5	4359.15	234.04
44.75	1572.80	140.58	59.75	2803.92	187.71	74.75	4388.46	234.83
45.	1590.43	141.37	60.	2827.43	188.49	75.	4417.86	235.61
45.25	1608.15	142.15	60.25	2851.04	189.28	75.25	4447.36	236.40
45.5	1625.97	142.94	60.5	2874.75	190.06	75.5	4476.96	237.19
45.75	1643.88	143.72	60.75	2898.56	190.85	75.75	4506.66	237.97
46.	1661.90	144.51	**61.**	2922.46	191.63	**76.**	4536.45	238.76
46.25	1680.01	145.29	61.25	2946.47	192.42	76.5	4596.34	240.33
46.5	1698.22	146.08	61.5	2970.57	193.20	77.	4656.62	241.90
46.75	1716.53	146.86	61.75	2894.77	193.99	77.5	4717.29	243.47
47.	1734.94	147.65	62.	3019.07	194.77	78.	4778.36	245.04
47.25	1753.45	148.44	62.25	3043.46	195.56	78.5	4839.81	246.61
47.5	1772.05	149.22	62.5	3067.96	196.34	79.	4901.66	248.18
47.75	1790.75	150.01	62.75	3092.55	197.13	79.5	4963.91	249.75
48.	1809.55	150.79	**63.**	3117.24	197.92	**80.**	5026.54	251.32
48.25	1828.45	151.58	63.25	3142.03	198.70	80.5	5089.57	252.89
48.5	1847.45	152.36	63.5	3166.92	199.49	81.	5152.99	254.46
48.75	1866.54	153.15	63.75	3191.90	200.27	81.5	5216.81	256.03
49.	1885.74	153.93	64.	3216.99	201.06	82.	5281.01	257.61
49.25	1905.83	154.72	64.25	3242.17	201.84	82.5	5345.61	259.18
49.5	1924.42	155.50	64.5	3267.45	202.63	83.	5410.60	260.75
49.75	1943.90	156.29	64.75	3292.83	203.41	83.5	5475.99	262.32
50.	1963.49	157.07	**65.**	3318.30	204.20	**84.**	5541.76	263.89
50.25	1983.17	157.96	65.25	3343.88	204.98	84.5	5607.93	265.46
50.5	2002.96	158.65	65.5	3369.55	205.77	85.	5674.50	267.03
50.75	2022.84	159.43	65.75	3395.32	206.55	85.5	5741.45	268.60
51.	2042.82	160.22	66.	3421.19	207.34	86.	5808.80	270.17
51.25	2062.89	161.00	66.25	3447.16	208.13	86.5	5876.54	271.74
51.5	2083.07	161.79	66.5	3473.22	208.91	87.	5944.67	273.31
51.75	2103.34	162.57	66.75	3499.39	209.70	87.5	6013.20	274.88
52.	2123.71	163.36	**67.**	3525.65	210.48	**88.**	6082.12	276.46
52.25	2144.18	164.14	67.25	3552.01	211.27	88.5	6151.43	278.03
52.5	2164.75	164.93	67.5	3578.47	212.05	89.	6221.13	279.60
52.75	2185.41	165.71	67.75	3605.02	212.84	89.5	6291.23	281.17
53.	2206.18	166.50	68.	3631.68	213.62	90.	6361.72	282.74
53.25	2227.04	167.28	68.25	3658.43	214.41	90.5	6432.60	284.31
53.5	2248.00	168.07	68.5	3685.28	215.19	91.	6503.88	285.88
53.75	2269.06	168.86	68.75	3712.23	215.98	91.5	6575.54	287.45
54.	2290.22	169.64	**69.**	3739.28	216.76	**92.**	6647.61	289.02
54.25	2311.47	170.43	69.25	3766.42	217.55	92.5	6720.06	290.59
54.5	2332.82	171.21	69.5	3793.66	218.34	93.	6792.90	292.16
54.75	2354.28	172.00	69.75	3821.01	219.12	93.5	6866.14	293.73
55.	2375.82	172.78	70.	3848.45	219.91	94.	6939.77	295.30
55.25	2397.47	173.57	70.25	3875.99	220.69	94.5	7013.80	296.88
55.5	2419.22	174.35	70.5	3903.62	221.48	95.	7088.21	298.45
55.75	2441.06	175.14	70.75	3931.36	222.27	95.5	7163.02	300.02
56.	2463.00	175.92	**71.**	3959.19	223.05	**96.**	7238.22	301.59
56.25	2485.04	176.71	71.25	3987.12	223.84	96.5	7313.82	303.16
56.5	2507.18	177.49	71.5	4015.15	224.62	97.	7389.81	304.73
56.75	2520.42	178.28	71.75	4043.28	225.41	97.5	7466.19	306.30
57.	2551.75	179.07	72.	4071.50	226.19	98.	7542.96	307.87
57.25	2574.19	179.85	72.25	4099.83	226.98	98.5	7620.12	309.44
57.5	2596.72	180.64	72.5	4128.24	227.76	99.	7697.68	311.01
57.75	2619.35	181.42	72.75	4156.77	228.55	99.5	7775.63	312.58
58.	2642.07	182.21	**73.**	4185.38	229.33	**100.**	7853.98	314.15

POWERS AND ROOTS.—TABLE 27

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, FIFTH POWERS AND RECIPROCALS.

From 1 to 50.

Num.	Squares.	Cubes.	Sq. Roots.	Cube Roots	Fifth Power.	Reciprocals.
1	1	1	1.000	1.000	1	.100000000
2	4	8	1.414	1.260	32	.500000000
3	9	27	1.732	1.442	243	.333333333
4	16	64	2.000	1.587	1024	.250000000
5	25	125	2.236	1.710	3125	.200000000
6	36	216	2.449	1.817	7776	.166666667
7	49	343	2.645	1.913	16807	.142857143
8	64	512	2.828	2.000	32768	.125000000
9	81	729	3.000	2.080	59049	.111111111
10	**100**	**1000**	**3.162**	**2.154**	**100000**	**.100000000**
11	121	1331	3.316	2.223	161051	.090909091
12	144	1728	3.464	2.289	248832	.083333333
13	169	2197	3.605	2.351	371293	.076923077
14	196	2744	3.741	2.410	537824	.071428571
15	225	3375	3.873	2.466	759375	.066666667
16	256	4096	4.000	2.520	1048576	.062500000
17	289	4913	4.123	2.571	1419857	.058823529
18	324	5832	4.242	2.620	1889568	.055555556
19	361	6859	4.359	2.668	2476099	.052631579
20	**400**	**8000**	**4.472**	**2.714**	**3200000**	**.050000000**
21	441	9261	4.582	2.759	4084101	.047619048
22	484	10648	4.690	2.802	5153632	.045454545
23	529	12167	4.796	2.844	6436343	.043478261
24	576	13824	4.899	2.884	7962624	.041666667
25	625	15625	5.000	2.924	9765625	.040000000
26	676	17576	5.099	2.962	11881376	.038461538
27	729	19683	5.196	3.000	14348907	.037037037
28	784	21952	5.291	3.036	17210368	.035714286
29	841	24389	5.385	3.072	20511149	.034482759
30	**900**	**27000**	**5.477**	**3.107**	**24300000**	**.033333333**
31	961	29791	5.567	3.141	28629151	.032258065
32	1024	32768	5.657	3.175	33554432	.031250000
33	1089	35937	5.744	3.207	39135393	.030303030
34	1156	39304	5.831	3.239	45435424	.029411765
35	1225	42875	5.916	3.271	52521875	.028571429
36	1296	46656	6.000	3.302	60466176	.027777778
37	1369	50653	6.082	3.332	69343957	.027027027
38	1444	54872	6.164	3.362	79235168	.026315789
39	1521	59319	6.245	3.391	90224199	.025641026
40	**1600**	**64000**	**6.324**	**3.420**	**102400000**	**.025000000**
41	1681	68921	6.403	3.448	115856201	.024390244
42	1764	74088	6.480	3.476	130691232	.023809524
43	1849	79507	6.557	3.503	147008443	.023255814
44	1936	85184	6.633	3.530	164916224	.022727273
45	2025	91125	6.708	3.557	184528125	.022222222
46	2116	97336	6.782	3.583	205962976	.021739130
47	2209	103823	6.855	3.609	229345007	.021276600
48	2304	110592	6.928	3.634	254803968	.020833333
49	2401	117649	7.000	3.659	282475249	.020408163
50	**2500**	**125000**	**7.071**	**3.684**	**312500000**	**.020000000**

POWERS AND ROOTS.—Table 27

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, FIFTH POWERS AND RECIPROCALS.

From 51 to 100.

Num.	Squares.	Cubes.	Sq. Roots.	Cube Roots.	Fifth Power.	Reciprocals.
51	2601	132651	7.141	3.708	345025251	.019607843
52	2704	140608	7.211	3.732	380204032	.019230769
53	2809	148877	7.280	3.756	418195493	.018867925
54	2916	157464	7.348	3.780	459165024	.018518519
55	3025	166375	7.416	3.803	503284375	.018181818
56	3136	175616	7.483	3.826	550731776	.017857143
57	3249	185193	7.549	3.848	601692057	.017543860
58	3364	195112	7.615	3.871	656356768	.017241379
59	3481	205379	7.681	3.893	714924299	.016949153
60	**3600**	**216000**	**7.745**	**3.915**	**777600000**	**.016666667**
61	3721	226981	7.810	3.936	844596301	.016393443
62	3844	238328	7.874	3.958	916132832	.016129032
63	3969	250047	7.937	3.979	992436543	.015873016
64	4096	262144	8.000	4.000	1073741824	.015625000
65	4225	274625	8.062	4.021	1160290625	.015384615
66	4356	287496	8.124	4.041	1252332576	.015151515
67	4489	300763	8.185	4.061	1350125107	.014925373
68	4624	314432	8.246	4.081	1453933568	.014705882
69	4761	328509	8.306	4.101	1564031349	.014492754
70	**4900**	**343000**	**8.366**	**4.121**	**1680700000**	**.014285714**
71	5041	357911	8.426	4.141	1804229351	.014084507
72	5184	373248	8.485	4.160	1934917632	.013888889
73	5329	389017	8.544	4.179	2073071593	.013698630
74	5476	405224	8.602	4.198	2219006624	.013513514
75	5625	421875	8.660	4.217	2373046875	.013333333
76	5776	438976	8.718	4.236	2535525376	.013157895
77	5929	456533	8.775	4.254	2706784157	.012987013
78	6084	474552	8.831	4.272	2887174368	.012820513
79	6241	493039	8.888	4.291	3077056399	.012658228
80	**6400**	**512000**	**8.944**	**4.309**	**3276800000**	**.012500000**
81	6561	531441	9.000	4.326	3486784401	.012345679
82	6724	551368	9.055	4.344	3707398432	.012195122
83	6889	571787	9.110	4.362	3939040643	.012048193
84	7056	592704	9.165	4.379	4182119424	.011904762
85	7225	614125	9.219	4.397	4437053125	.011764706
86	7396	636056	9.273	4.414	4704270176	.011627907
87	7569	658503	9.327	4.431	4984209207	.011494253
88	7744	681472	9.381	4.447	5277319168	.011363636
89	7921	704969	9.434	4.464	5584059449	.011235955
90	**8100**	**729000**	**9.487**	**4.481**	**5904900000**	**.011111111**
91	8281	753571	9.539	4.498	6240321451	.010989011
92	8464	778688	9.591	4.514	6590815232	.010869565
93	8649	804357	9.643	4.530	6956883693	.010752688
94	8836	830584	9.695	4.547	7339040224	.010638298
95	9025	857375	9.746	4.563	7737809375	.010526316
96	9216	884736	9.798	4.579	8153726976	.010416667
97	9409	912673	9.849	4.594	8587340257	.010309278
98	9604	941192	9.899	4.610	9039207968	.010204082
99	9801	970299	9.950	4.626	9509900499	.010101010
100	**10000**	**100000**	**10000**	**4.641**	**10000000000**	**.010000000**

POWERS AND ROOTS.—Table 27a

SQUARES, SQUARE ROOTS, AND CUBE ROOTS.

From 101 to 200.

Num.	Squares.	Square Roots	Cube Roots.	Num.	Squares.	Square Roots	Cube Roots
101	10201	10.050	4.657	151	22801	12.288	5.325
102	10404	10.099	4.672	152	23104	12.329	5.337
103	10609	10.149	4.687	153	23409	12.369	5.348
104	10816	10.198	4.702	154	23716	12.409	5.360
105	11025	10.247	4.717	155	24025	12.450	5.371
106	11236	10.295	4.732	156	24336	12.490	5.383
107	11449	10.344	4.747	157	24649	12.530	5.394
108	11664	10.392	4.762	158	24964	12.570	5.406
109	11881	10.440	4.777	159	25281	12.609	5.417
110	**12100**	**10.488**	**4.791**	**160**	**25600**	**12.649**	**5.429**
111	12321	10.535	4.806	161	25921	12.688	5.440
112	12544	10.583	4.820	162	26244	12.728	5.451
113	12769	10.630	4.834	163	26569	12.767	5.462
114	12996	10.677	4.849	164	26896	12.806	5.474
115	13225	10.724	4.863	165	27225	12.845	5.485
116	13456	10.770	4.877	166	27556	12.884	5.496
117	13689	10.816	4.891	167	27889	12.923	5.507
118	13924	10.863	4.905	168	28224	12.961	5.518
119	14161	10.909	4.918	169	28561	13.000	5.528
120	**14400**	**10.954**	**4.932**	**170**	**28900**	**13.038**	**5.539**
121	14641	11.000	4.946	171	29241	13.076	5.550
122	14884	11.045	4.959	172	29584	13.115	5.561
123	15129	11.090	4.973	173	29929	13.153	5.572
124	15376	11.135	4.986	174	30276	13.191	5.583
125	15625	11.180	5.000	175	30625	13.229	5.593
126	15876	11.225	5.013	176	30976	13.266	5.604
127	16129	11.269	5.026	177	31329	13.304	5.614
128	16384	11.313	5.039	178	31684	13.341	5.625
129	16641	11.358	5.052	179	32041	13.379	5.636
130	**16900**	**11.402**	**5.065**	**180**	**32.400**	**13.416**	**5.646**
131	17161	11.445	5.078	181	32761	13.453	5.656
132	17424	11.489	5.091	182	33124	13.490	5.667
133	17689	11.532	5.104	183	33489	13.527	5.677
134	17956	11.576	5.117	184	33856	13.564	5.688
135	18225	11.619	5.130	185	34225	13.601	5.698
136	18496	11.662	5.142	186	34596	13.638	5.708
137	18769	11.704	5.155	187	34969	13.675	5.718
138	19044	11.747	5.167	188	35344	13.711	5.728
139	19321	11.790	5.180	189	35721	13.747	5.739
140	**19600**	**11.832**	**5.192**	**190**	**36.100**	**13.784**	**5.749**
141	19881	11.874	5.204	191	36481	13 820	5.759
142	20164	11.916	5.217	192	36864	13.856	5.769
143	20449	11.958	5.229	193	37249	13.892	5.779
144	20736	12.000	5.241	194	37636	13.928	5.789
145	21025	12.041	5.253	195	38025	13.964	5.799
146	21316	12.083	5.265	196	38416	14.000	5.809
147	21609	12.124	5.277	197	38809	14.035	5.818
148	21904	12.165	5.289	198	39204	14.071	5.828
149	22201	12.206	5.301	199	39601	14.107	5.838
150	**22500**	**12.247**	**5.313**	**200**	**40000**	**14.142**	**5.848**

POWERS AND ROOTS.—Table 27a

SQUARES, SQUARE ROOTS, AND CUBE ROOTS.

From 201 to 300.

Num.	Squares.	Square Roots	Cube Roots.	Num.	Squares.	Square Roots	Cube Roots.
201	40401	14.177	5.858	251	63001	15.843	6.308
202	40804	14.212	5.867	252	63504	15.874	6.316
203	41209	14.248	5.877	253	64009	15.906	6.325
204	41616	14.283	5.887	254	64516	15.937	6.333
205	42025	14.318	5.896	255	65025	15.969	6.341
206	42436	14.353	5.906	256	65536	16.000	6.349
207	42849	14.387	5.915	257	66049	16.031	6.358
208	43264	14.422	5.925	258	66564	16.062	6.366
209	43681	14.456	5.934	259	67081	16.093	6.374
210	**44100**	**14.491**	**5.943**	**260**	**67600**	**16.124**	**6.382**
211	44521	14.526	5.953	261	68121	16.155	6.390
212	44944	14.560	5.962	262	68644	16.186	6.399
213	45369	14.594	5.972	263	69169	16.217	6.407
214	45796	14.629	5.981	264	69696	16.248	6.415
215	46225	14.662	5.991	265	70225	16.279	6.423
216	46656	14.697	6.000	266	70756	16.309	6.431
217	47089	14.731	6.009	267	71289	16.340	6.439
218	47524	14.765	6.018	268	71824	16.371	6.447
219	47961	14.798	6.027	269	72361	16.401	6.455
220	**48400**	**14.832**	**6.037**	**270**	**72900**	**16.431**	**6.463**
221	48841	14.866	6.045	271	73441	16.462	6.471
222	49284	14.899	6.055	272	73984	16.492	6.479
223	49729	14.933	6.064	273	74529	16.522	6.487
224	50176	14.966	6.073	274	75076	16.552	6.495
225	50625	15.000	6.082	275	75625	16.583	6.503
226	51076	15.033	6.091	276	76176	16.613	6.511
227	51529	15.066	6.100	277	76729	16.643	6.518
228	51984	15.099	6.109	278	77284	16.678	6.526
229	52441	15.133	6.118	279	77841	16.703	6.534
230	**52900**	**15.166**	**6.126**	**280**	**78400**	**16.733**	**6.542**
231	53361	15.198	6.135	281	78961	16.763	6 550
232	53824	15.231	6.144	282	79524	16.793	6.557
233	54289	15.264	6.153	283	80089	16.822	6.565
234	54756	15.297	6.162	284	80656	16.852	6.573
235	55225	15.330	6.171	285	81225	16.882	6.581
236	55696	15.362	6.179	286	81796	16.911	6.588
237	56169	15.395	6.188	287	82369	16.941	6.596
238	56644	15.427	6.197	288	82944	16.970	6.604
239	57121	15.459	6.205	289	83521	17.000	6.611
240	**57600**	**15.492**	**6.214**	**290**	**84100**	**1.7029**	**6.619**
241	58081	15 524	6.223	291	84681	17.058	6.627
242	58564	15.556	6.231	292	85264	17.088	6.634
243	59049	15.588	6.240	293	85849	17.117	6.642
244	59536	15.620	6.249	294	86436	17.146	6.649
245	60025	15.652	6.257	295	87025	17.175	6.657
246	60516	15.684	6.266	296	87616	17.204	6.664
247	61009	15.716	6.274	297	88209	17.233	6.672
248	61504	15.748	6.283	298	88804	17.262	6.679
249	62001	15.780	6.291	299	89401	17.291	6.687
250	**62500**	**15.811**	**6.299**	**300**	**90000**	**17320**	**6.694**

POWERS AND ROOTS.—Table 27a

SQUARES, SQUARE ROOTS, AND CUBE ROOTS.

From 301 to 400.

Num.	Squares.	Square Roots.	Cube Roots.	Num.	Squares.	Square Roots.	Cube Roots.
301	90601	17.349	6.702	351	123201	18.735	7.054
302	91204	17.378	6.709	352	123904	18.761	7.060
303	91809	17.407	6.716	353	124609	18.788	7.067
304	92416	17.435	6.724	354	125316	18.815	7.074
305	93025	17.464	6.731	355	126025	18.841	7.080
306	93636	17.493	6.738	356	126736	18.868	7.087
307	94249	17.521	6.746	357	127449	18.894	7.094
308	94864	17.550	6.753	358	128164	18.921	7.100
309	95481	17.578	6.760	359	128881	18.947	7.107
310	**96100**	**17.607**	**6.786**	**360**	**129600**	**18.973**	**7.114**
311	96721	17.635	6.775	361	130321	19.000	7.120
312	97344	17.663	6.782	362	131044	19.026	7.127
313	97969	17.692	6.789	363	131769	19.052	7.133
314	98596	17.720	6.797	364	132496	19.078	7.140
315	99225	17.748	6.804	365	133225	19.105	7.146
316	99856	17.776	6.811	366	133956	19.131	7.153
317	100489	17.804	6.818	367	134689	19.157	7.159
318	101124	17.832	6.825	368	135424	19.183	7.166
319	101761	17.860	6.833	369	136161	19.209	7.172
320	**102400**	**17.888**	**6.840**	**370**	**136900**	**19.235**	**7.179**
321	103041	17.916	6.847	371	137641	19.261	7.185
322	103684	17.944	6.854	372	138384	19.287	7.192
323	104329	17.972	6.861	373	139129	19.313	7.198
324	104976	18.000	6.868	374	139876	19.339	7.205
325	105625	18.028	6.875	375	140625	19.365	7.211
326	106276	18.055	6.882	376	141376	19.391	7.217
327	106929	18.083	6.889	377	142129	19.416	7.224
328	107584	18.111	6.896	378	142884	19.442	7.230
329	108241	18.138	6.903	379	143641	19.468	7.237
330	**108900**	**18.166**	**6.910**	**380**	**144400**	**19.493**	**7.243**
331	109561	18.193	6.917	381	145161	19.519	7.249
332	110224	18.221	6.924	382	145924	19.545	7.256
333	110889	18.248	6.931	383	146689	19.570	7.262
334	111556	18.275	6.938	384	147456	19.596	7.268
335	112225	18.303	6.945	385	148225	19.621	7.275
336	112896	18.330	6.952	386	148996	19.649	7.281
337	113569	18.357	6.959	387	149769	19.672	7.287
338	114244	18.385	6.966	388	150544	19.698	7.293
339	114921	18.412	6.972	389	151321	19.723	7.300
340	**115600**	**18.439**	**6.979**	**390**	**152100**	**19.748**	**7.306**
341	116281	18.466	6.986	391	152881	19.774	7.312
342	116964	18.493	6.993	392	153664	19.799	7.318
343	117649	18.520	7.000	393	154449	19.824	7.325
344	118336	18.547	7.007	394	155236	19.849	7.331
345	119025	18.574	7.013	395	156025	19.874	7.337
346	119716	18.601	7.020	396	156816	19.900	7.343
347	120409	18.628	7.027	397	157609	19.925	7.349
348	121104	18.655	7.034	398	158404	19.950	7.356
349	121801	18.681	7.040	399	159201	19.975	7.362
350	**122500**	**18.708**	**7.**	**400**	**160000**	**20.000**	**7.358**

POWERS AND ROOTS.—TABLE 27a

SQUARES, SQUARE ROOTS, AND CUBE ROOTS.

From 401 to 500

Num.	Squares.	Square Roots	Cube Roots.	Num.	Squares.	Square Roots	Cube Roots.
401	160801	20.025	7.374	451	203401	21.236	7.669
402	161604	20.050	7.380	452	204304	21.260	7.674
403	162409	20.075	7.386	453	205209	21.284	7.680
404	163216	20.100	7.392	454	206116	21 307	7.686
405	164025	20.124	7.398	455	207025	21.331	7.691
406	164836	20.149	7.405	456	207936	21.354	7.697
407	165649	20.174	7.411	457	208849	21.377	7.702
408	166464	20.199	7.417	458	209764	21.401	7.708
409	167281	20.224	7.423	459	210681	21.424	7.719
410	**168100**	**20.248**	**7.429**	**460**	**211600**	**21.447**	**7.719**
411	168921	20.273	7.435	461	212521	21.471	7.725
412	169744	20.298	7.441	462	213444	21.494	7.730
413	170569	20.322	7.447	463	214369	21.517	7.736
414	171396	20.347	7.453	464	215296	21.540	7.742
415	172225	20.371	7.459	465	216225	21.564	7.747
416	173056	20.396	7.465	466	217156	21.587	7.753
417	173889	20.420	7.471	467	218089	21.610	7.758
418	174724	20.445	7.477	468	219024	21.633	7.764
419	175561	20.469	7.483	469	219961	21.656	7.769
420	**176400**	**20.494**	**7.489**	**470**	**220900**	**21.679**	**7.775**
421	177241	20.518	7.495	471	221841	21.702	7.780
422	178084	20.542	7.501	472	222784	21.725	7.786
423	178929	20.567	7.506	473	223729	21.748	7.791
424	179776	20.591	7.512	474	224676	21.771	7.797
425	180625	20.615	7.518	475	225625	21.794	7.802
426	181476	20.640	7.524	476	226576	21.817	7.808
427	182329	20.664	7.530	477	227529	21.840	7.813
428	183184	20.688	7.536	478	228484	21.863	7.819
429	184041	20.712	7.542	479	229441	21.886	7.824
430	**184900**	**20.736**	**7.548**	**480**	**230400**	**21.909**	**7.830**
431	185761	20.760	7.553	481	231361	21.932	7.835
432	186624	20.784	7.559	482	232324	21.954	7.840
433	187489	20.808	7.565	483	233289	21.977	7.846
434	188356	20.832	7.571	484	234256	22.000	7.851
435	189225	20.856	7.577	485	235225	22.023	7.857
436	190096	20.880	7.583	486	236196	22.045	7.862
437	190969	20.904	7.588	487	237169	22.068	7.867
438	191844	20.928	7.594	488	238144	22.091	7.873
439	192721	20.952	7.600	489	239121	22.113	7.878
440	**193600**	**20.976**	**7.606**	**490**	**240100**	**22.136**	**7.884**
441	194481	21.000	7.611	491	241081	22.158	7.889
442	195364	21.024	7.617	492	242064	22.181	7.894
443	196249	21.047	7.623	493	243049	22.203	7.900
444	197136	21.071	7.629	494	244036	22.226	7.905
445	198025	21.095	7.634	495	245025	22.248	7.910
446	198916	21.119	7.640	496	246016	22.271	7.916
447	199809	21.142	7.646	497	247009	22.293	7.921
448	200704	21.166	7.652	498	248004	22.316	2.926
449	201601	21.189	7.657	499	249001	22.338	7.932
450	**202500**	**21.213**	**7.663**	**500**	**250000**	**22.360**	**7.937**

POWERS AND ROOTS.—TABLE 27a

SQUARES, SQUARE ROOTS, AND CUBE ROOTS.

From 501 to 600

Num.	Squares.	Square Roots	Cube Roots.	Num.	Squares.	Square Roots	Cube Roots.
501	251001	22.383	7.942	551	303601	23.473	8.198
502	252004	22.405	7.947	552	304704	23.494	8.203
503	253009	22.427	7.953	553	305809	23.516	8.208
504	254016	22.450	7.958	554	306916	23.537	8.213
505	255025	22.472	7.963	555	308025	23.558	8.218
506	256036	22.494	7.968	556	309136	23.579	8.223
507	257049	22.516	7.974	557	310249	23.601	8.228
508	258064	22.539	7.979	558	311364	23.622	8.233
509	259081	22.561	7.984	559	312481	23.643	8.237
510	**260100**	**22.583**	**7.989**	**560**	**313600**	**23.664**	**8.242**
511	261121	22.605	7.995	561	314721	23.685	8.247
512	262144	22.627	8.000	562	315844	23.706	8.252
513	263169	22.649	8.005	563	316969	23.727	8.257
514	264196	22.671	8.010	564	318096	23.748	8.262
515	265225	22.693	8.015	565	319225	23.770	8.267
516	266256	22.715	8.021	566	320356	23.791	8.272
517	267289	22.737	8.026	567	321489	23.812	8.277
518	268324	22.759	8.031	568	322624	23.833	8.281
519	269361	22.781	8.036	569	323761	23.854	8.286
520	**270400**	**22.803**	**8.041**	**570**	**324900**	**23.874**	**8.291**
521	271411	22.825	8.046	571	326041	23.895	8.296
522	272484	22.847	8.052	572	327184	23.916	8.301
523	273529	22.869	8.057	573	328329	23.937	8.306
524	274576	22.891	8.062	574	329476	23.958	8.310
525	275625	22.913	8.067	575	330625	23.979	8.315
526	276676	22.934	8.072	576	331776	24.000	8.320
527	277729	22.956	8.077	577	332929	24.021	8.325
528	278784	22.978	8.082	578	334084	24.041	8.330
529	279841	23.000	8.087	579	335241	24.062	8.335
530	**280900**	**23.022**	**8.092**	**580**	**336400**	**24.083**	**8.339**
531	281961	23.043	8.098	581	337561	24.104	8.344
532	283024	23.065	8.103	582	338724	24.124	8.349
533	284089	23.087	8.108	583	339889	24.145	8.354
534	285156	23.108	8.113	584	341056	24.166	8.358
535	286225	23.130	8.118	585	342225	24.187	8.363
536	287296	23.151	8.123	586	343396	24.207	8.368
537	288369	23.173	8.128	587	344569	24.228	8.373
538	289444	23.195	8.133	588	345744	24.249	8.378
539	290521	23.216	8.138	589	346921	24.269	8.382
540	**291600**	**23.238**	**8.143**	**590**	**348100**	**24.290**	**8.387**
541	292681	23.259	8.148	591	349281	24.310	8.392
542	293764	23.281	8.153	592	350464	24.331	8.396
543	294849	23.302	8.158	593	351649	24.351	8.401
544	295936	23.324	8.163	594	352836	24.372	8.406
545	297025	23.345	8.168	595	354025	24.392	8.411
546	298116	23.366	8.173	596	355216	24.413	8.415
547	299209	23.388	8.178	597	356409	24.433	8.420
548	300304	23.409	8.183	598	357604	24.454	8.425
549	301401	23.431	8.188	599	358801	24.474	8.429
550	**302500**	**23.452**	**8.193**	**600**	**360000**	**24.495**	**8.434**

POWERS AND ROOTS.—Table 27a

SQUARES, SQUARE ROOTS, AND CUBE ROOTS.

From 601 to 700

Num.	Squares.	SquareRoots	Cube Roots.	Num.	Squares.	SquareRoots	Cube Roots.
601	361201	24.515	8.439	651	423801	25.515	8.667
602	362404	24.535	8.443	652	425104	25.534	8.671
603	363609	24.556	8.448	653	426409	25.554	8.675
604	364816	24.576	8.453	654	427716	25.573	8.680
605	366025	24.597	8.457	655	429025	25.593	8.684
606	367236	24.617	8.462	656	430336	25.612	8.689
607	368449	24.637	8.467	657	431639	25.632	8.693
608	369664	24.657	8.471	658	432964	25.651	8.698
609	370881	24.678	8.476	659	434281	25.671	8.702
610	**372100**	**24.698**	**8.481**	**660**	**435600**	**25.690**	**8.706**
611	373321	24.718	8.485	661	436921	25.710	8.711
612	374544	24.738	8.490	662	438244	25.729	8.715
613	375769	24.759	8.495	663	439569	25.749	8.720
614	376996	24.779	8.499	664	440896	25.768	8.724
615	378225	24.799	8.504	665	442225	25.787	8.728
616	379456	24.819	8 508	666	443556	25.807	8.733
617	380689	24.839	8.513	667	444899	25.826	8.737
618	381924	24.859	8.518	668	446224	25.845	8.741
619	383161	24.880	8.522	669	447561	25.865	8.746
620	**384400**	**24.900**	**8.527**	**670**	**448900**	**25.884**	**8.750**
621	385641	24.920	8.531	671	450241	25.903	8.754
622	386884	24.940	8.536	672	451584	25.923	8.759
623	388129	24.960	8.541	673	452929	25.942	8.763
624	389376	24.980	8.545	674	454276	25.961	8.768
625	390625	25.000	8.550	675	455625	25.981	8.772
626	391876	25.020	8.554	676	456976	26.000	8.776
627	393129	25.040	8.559	677	458329	26.019	8.781
628	394384	25.060	8.563	678	459684	26.038	8.785
629	395641	25.080	8.568	679	461041	26.057	8.789
630	**396900**	**25.100**	**8.572**	**680**	**462400**	**26.077**	**8.793**
631	398161	25.120	8.577	681	463761	26.096	8.798
632	399424	25.140	8.581	682	465124	26.115	8.802
633	400689	25.159	8.586	683	466489	26.134	8.806
634	401956	25.179	8.591	684	467856	26.153	8.811
635	403225	25.199	8.595	685	469225	26.172	8.815
636	404496	25.219	8.600	686	470596	26.191	8.819
637	405769	25.239	8.604	687	471969	26.210	8.824
638	407044	25.258	8.609	688	473344	26.230	8.828
639	408321	25.278	8.613	689	474721	26.249	88.32
640	**409600**	**25.298**	**8.618**	**690**	**476100**	**26.268**	**8.836**
641	410881	25.318	8.622	691	477481	26.287	8.841
642	412164	25 338	8.627	692	478864	26.306	8.845
643	413449	25.357	8.631	693	480249	26.325	8.849
644	414736	25.377	8.635	694	481636	26.344	8.853
645	416125	25.397	8.640	695	483025	26.363	8.858
646	417316	25.416	8.644	696	484416	26.382	8.862
647	418609	25.436	8.649	697	485809	26.401	8.866
648	419904	25.456	8.653	698	487204	26.419	8.870
649	421201	25.475	8.658	699	488601	26.438	8.875
650	**422500**	**25.495**	**8.662**	**700**	**490.000**	**26.457**	**8.879**

POWERS AND ROOTS.—Table 27a

SQUARES, SQUARE ROOTS, AND CUBE ROOTS.

From 701 to 800.

Num.	Squares.	Square Roots	Cube Roots.	Num.	Squares.	Square Roots	Cube Roots.
701	491401	26.476	8.883	751	564001	27.404	9.089
702	492804	26.495	8.887	752	565504	27.422	9.093
703	494209	26.514	8.891	753	567000	27.441	9.098
704	495616	26.533	8.896	754	568516	27.459	9.102
705	497025	26.552	8.900	755	570025	27.477	9.106
706	498436	26.570	8.904	756	571536	27.495	9.110
707	499849	26.589	8.908	757	573049	27.513	9.114
708	501264	26.608	8.913	758	574564	27.532	9.118
709	502681	26.627	8.917	759	576081	27.550	9.122
710	**504100**	**26.646**	**8.921**	**760**	**577600**	**27.568**	**9.126**
711	505521	26.664	8.925	761	579121	27.586	9.130
712	506944	26.683	8.929	762	580644	27.604	9.134
713	508369	26.702	8.933	763	582169	27.622	9.138
714	509796	26.721	8.938	764	583696	27.640	9.142
715	511225	26.739	8.942	765	585225	27.658	9.146
716	512656	26.758	8.946	766	586756	27.677	9.150
717	514089	26.777	8.950	767	588289	27.695	9.154
718	515524	26.795	8.954	768	589824	27.713	9.158
719	516961	26.814	8.958	769	591361	27.731	9.161
720	**518400**	**26.833**	**8.963**	**770**	**592900**	**27.749**	**9.165**
721	519841	26.851	8.967	771	594441	27.767	9.169
722	521284	26.870	8.971	772	595984	27.785	9.173
723	522729	26.888	8.975	773	597529	27.803	9.177
724	524176	26.907	8.979	774	599076	27.821	9.181
725	525625	26.926	8.983	775	600625	27.839	9.185
726	527076	26.944	8.987	776	602176	27.857	9.189
727	528529	26.963	8.992	777	603729	27.875	9.193
728	529984	26.981	8.996	778	605284	27.892	9.197
729	531441	27.000	9.000	779	606841	27.910	9.201
730	**532900**	**27.018**	**9.004**	**780**	**608400**	**27.928**	**9.205**
731	534361	27.037	9.008	781	609961	27.946	9 209
732	535824	27.055	9.012	782	611524	27.964	9.213
733	537289	27.074	9.016	783	613089	27.982	9.217
734	538756	27.092	9.020	784	614656	28.000	9.221
735	540225	27.111	9.024	785	616225	28.018	9.225
736	541696	27.129	9.029	786	617796	28.035	9.229
737	543169	27.148	9.033	787	619369	28.053	9.232
738	544644	27.166	9.037	788	620944	28.071	9.236
739	546121	27.184	9.041	789	622521	28.089	9.240
740	**547600**	**27.203**	**9.045**	**790**	**624100**	**28.107**	**9.244**
741	549801	27.221	9.049	791	625681	28.125	9.248
742	550564	27.239	9.053	792	627624	28.142	9.252
743	552049	27.258	9.057	793	628849	28.160	9.256
744	553536	27.276	9.061	794	630436	28.178	9.260
745	555025	27.294	9.065	795	632025	28.196	9.264
746	556516	27.313	9.069	796	633616	28.213	9.267
747	558009	27.331	9.073	797	635209	28.231	9.271
748	559504	27.349	9.077	798	636804	28.247	9.275
749	561001	27.368	9.081	799	638401	28.266	9.279
750	**562500**	**27.386**	**9.085**	**800**	**640000**	**28.284**	**9.283**

SQUARES, SQUARE ROOTS, AND CUBE ROOTS.

From 801 to 900

Num.	Squares.	Square Roots	Cube Roots.	Num.	Squares.	Square Roots	Cube Roots
801	641601	28.302	9.287	851	724201	29.172	9.476
802	643204	28.319	9.291	852	725904	29.189	9.480
803	644809	28.337	9.295	853	727609	29.206	9.484
804	646416	28.355	9.298	854	729316	29.223	9.487
805	648025	28.372	9.302	855	731025	29.240	9.491
806	649636	28.390	9.306	856	732736	29.257	9.495
807	651249	28.408	9.310	857	734449	29.274	9.498
808	652864	28.425	9.314	858	736164	29.291	9.502
809	654481	28.443	9.318	859	737881	29.309	9.506
810	**656100**	**28.460**	**9.321**	**860**	**739600**	**29.326**	**9.509**
811	657721	28.478	9.325	861	741321	29.343	9.513
812	659344	28.495	9.329	862	743044	29.360	9.517
813	660969	28.513	9.333	863	744769	29.377	9.521
814	662596	28.530	9.337	864	746496	29.394	9.524
815	664225	28.548	9.341	865	748225	29.411	9.528
816	665856	28.566	9.344	866	749956	29.428	9.532
817	667489	28.583	9.348	867	751689	29.445	9.535
818	669124	28.600	9.352	868	753424	29.462	9.539
819	670761	28.618	9.356	869	755161	29.479	9.543
820	**672400**	**28.635**	**9.360**	**870**	**756900**	**29.496**	**9.546**
821	674041	28.653	9.364	871	758641	29.513	9.550
822	675684	28.670	9.367	872	760384	29.529	9.554
823	677329	28.688	9.371	873	762129	29.546	9.557
824	678976	28.705	9.375	874	763876	29.563	9.561
825	680625	28.723	9.379	875	765625	29.580	9.564
826	682276	28.740	9.382	876	767376	29.597	9.568
827	683929	28.757	9.386	877	769129	29.614	9.572
828	685584	28.775	9.390	878	770884	29.631	9.575
829	687241	28.792	9.394	879	772641	29.648	9.579
830	**688900**	**28.810**	**9.398**	**880**	**774400**	**29.665**	**9.583**
831	690561	28.827	9.401	881	776161	29.681	9.586
832	692224	28.844	9.405	882	777924	29.698	9.590
833	693889	28.862	9.409	883	779689	29.715	9.594
834	695556	28.879	9.413	884	781456	29.732	9.597
835	697225	28.896	9.416	885	783225	29.749	9.601
836	698896	28.913	9.420	886	784996	29.766	9.604
837	700569	28.931	9.424	887	786769	29.782	9.608
838	702244	28.948	9.428	888	788544	29.799	9.612
839	703921	28.965	9.431	889	790321	29.816	9.615
840	**705600**	**28.983**	**9.435**	**890**	**792100**	**29.833**	**9.619**
841	707281	29.000	9.439	891	793881	29.849	9.622
842	708964	29.017	9.443	892	795664	29.866	9.626
843	710649	29.034	9.446	893	797449	29.883	9.630
844	712336	29.051	9.450	894	799236	29.900	9.633
845	714025	29.069	9.454	895	801025	29.916	9.637
846	715716	29.086	9.458	896	802816	29.933	9.640
847	717409	29.103	9.461	897	804609	29.950	9.644
848	719104	29.120	9.465	898	806404	29.966	9.648
849	720801	29.137	9.469	899	808201	29.983	9.651
850	**722500**	**29.155**	**9.472**	**900**	**810000**	**30.000**	**9.655**

POWERS AND ROOTS.—Table 27a.

SQUARES, SQUARE ROOTS, AND CUBE ROOTS.

From 901 to 1,000.

Num.	Squares.	Square Roots	Cube Roots.	Num.	Squares.	Square Roots	Cube Roots.
901	811801	30.017	9.658	951	904401	30.838	9.834
902	813604	30.033	9.662	952	906304	30.854	9.837
903	815409	30.050	9.666	953	908209	30.870	9.841
904	817216	30.066	9.669	954	910116	30.887	9.844
905	819025	30.083	9.672	955	912025	30.903	9.847
906	820836	30.100	9.676	956	913936	30.919	9.851
907	822649	30.116	9.680	957	915849	30.935	9.854
908	824464	30.133	9.683	958	917764	30.951	9.858
909	826281	30.150	9.687	959	919681	30.968	9.861
910	**828100**	**30.166**	**9.690**	**960**	**921600**	**30.984**	**9.865**
911	829921	30.183	9.694	961	923521	31.000	9.868
912	831744	20.199	9.697	962	925444	31.016	9.871
913	833569	30.216	9.701	963	927369	31.032	9.875
914	835396	30.232	9.705	964	929296	31.048	9.878
915	837225	30.249	9.708	965	931225	31.064	9.882
916	839056	30.265	9.712	966	933156	31.080	9.885
917	840889	30.282	7.715	967	935089	31.096	9.889
918	842724	30.298	9.719	968	937024	31.112	9.892
919	844561	30.315	9.722	969	938961	31.129	9.895
920	**846400**	**30.331**	**9.726**	**970**	**940900**	**31.145**	**9.899**
921	848241	30.348	9.729	971	942841	31.161	9.902
922	850084	30.364	9.733	972	944784	31.177	9.906
923	851929	30.381	9.736	973	946729	31.193	9.909
924	853776	30.397	9.740	974	948676	31.209	9.912
925	855625	30.414	9.743	975	950625	31.225	9.916
926	857476	30.430	9.747	976	952576	31.241	9.919
927	859329	30.446	9.750	977	954529	31.257	9.923
928	861184	30.463	9.754	978	956484	31.273	9.926
929	863041	30.479	9.757	979	958441	31.289	9.929
930	**864900**	**30.496**	**9.761**	**980**	**960400**	**31.305**	**9.933**
931	866761	30.512	9.764	981	962361	31.321	9.936
932	868624	30.528	9.768	982	964324	31.337	9.939
933	870489	30.545	9.771	983	966289	31.353	9.943
934	872356	30.561	9.775	984	968256	31.369	9.946
935	874225	30.578	9.778	985	970225	31.385	9.950
936	876096	30.594	9.782	986	972196	31.400	9.953
937	877969	30.610	9.785	987	974169	31.416	9.956
938	879844	30.627	9.789	988	976144	31.432	9.960
939	881721	30.643	9.792	989	978121	31.448	9.963
940	**883600**	**30.659**	**9.796**	**990**	**980100**	**31.464**	**9.966**
941	885481	30.676	9.799	991	982081	31.480	9.970
942	887364	30.692	9.803	992	984064	31.496	9.973
943	889249	30.708	9.806	993	986049	31.512	9.976
944	891136	30.724	9.810	994	988036	31.528	9.980
945	893025	30.741	9.813	995	990025	31.543	9.983
946	894916	30.757	9.816	996	992016	31.559	9.986
947	896809	30.773	9.820	997	994009	31.575	9.990
948	898704	30.789	9.823	998	996004	31.591	9.993
949	900601	30.806	9.827	999	998001	31.607	9.996
950	**902500**	**30.822**	**9.830**	**1000**	**1000000**	**31.623**	**10.000**

POWERS AND ROOTS.—TABLE 27a.

SQUARES, SQUARE ROOTS, AND CUBE ROOTS.

From 1,001 to 1,100.

Num.	Squares.	SquareRoots	Cube Roots	Num.	Squares.	SquareRoots	Cube Roots.
1001	1000201	31.638	10.003	1051	1104601	32 419	10.167
1002	1004004	31.654	10.006	1052	1106704	32.434	10.170
1003	1006009	31.670	10.010	1053	1108809	32.450	10.173
1004	1008016	31.686	10.013	1054	1110916	32.465	10.176
1005	1010025	31.702	10.016	1055	1113025	32.481	10.180
1006	1012036	31.717	10.020	1056	1115136	32.496	10.183
1007	1014049	31.733	10.023	1057	1117249	32.511	10 186
1008	1016064	31.749	10.026	1058	1119364	32.527	10.190
1009	1018081	31.765	10.030	1059	1121481	32.542	10.193
1010	**1020100**	**31.780**	**10.033**	**1060**	**1123600**	**32.558**	**10.196**
1011	1022121	31.796	10.036	1061	1125721	32.573	10.199
1012	1024144	31.812	10.039	1062	1127844	32.588	10.202
1013	1026169	31.828	10.043	1063	1129969	32.603	10.205
1014	1028196	31.843	10.046	1064	1132096	32.619	10.209
1015	1030225	31.859	10.050	1065	1134225	32.634	10.212
1016	1032256	31.875	10.053	1066	1136356	32.650	10.215
1017	1034289	31.890	10.056	1067	1138489	32.665	10.218
1018	1036324	31.906	10.059	1068	1140624	32.680	10.221
1019	1038361	31.922	10.063	1069	1142761	32.696	10.225
1020	**1040400**	**31.937**	**10.066**	**1070**	**1144900**	**32.711**	**10.228**
1021	1042441	31.953	10.069	1071	1147041	32.726	10.231
1022	1044484	31.969	10.073	1072	1149184	32.741	10.234
1023	1046529	31.984	10.076	1073	1151329	32.757	10.237
1024	1048576	32.000	10.079	1074	1153476	32.772	10.240
1025	1050625	32.016	10.082	1075	1155625	32.787	10.244
1026	1052676	32.031	10.086	1076	1157776	32.802	10.247
1027	1054729	32.047	10.089	1077	1159929	32.818	10.250
1028	1056784	32.062	10.092	1078	1162084	32.833	10.253
1029	1058841	32.078	10.096	1079	1164241	32.848	10.257
1030	**1060900**	**32.094**	**10.099**	**1080**	**1166400**	**32.863**	**10.260**
1031	1062961	32.109	10.102	1081	1168561	32.879	10.263
1032	1065024	32.125	10.105	1082	1170724	32.894	10.266
1033	1067089	32.140	10.109	1083	1172889	32.909	10.269
1034	1069156	32.156	10.112	1084	1175056	32.924	10.272
1035	1071225	32.171	10.115	1085	1177225	32.939	10.276
1036	1073296	32.187	10.118	1086	1179396	32.954	10.279
1037	1075369	32.202	10.121	1087	1181569	32.970	10.282
1038	1077444	32.218	10.125	1088	1183744	32.985	10.285
1039	1079521	32.233	10.128	1089	1185921	33.000	10.288
1040	**1081600**	**32.249**	**10.131**	**1090**	**1188100**	**33.015**	**10.291**
1041	1083681	32.264	10.134	1091	1190281	33.030	10.295
1042	1085764	32.280	10.138	1092	1192464	33.045	10.298
1043	1087849	32.295	10.141	1093	1194649	33.061	10.301
1044	1089936	32.311	10.144	1094	1196836	33.076	10.304
1045	1092025	32.326	10.148	1095	1199025	33.091	10.307
1046	1094116	32.342	10.151	1096	1201216	33.106	10.310
1047	1096209	32.357	10.154	1097	1203409	33.121	10.313
1048	1098304	32.373	10.157	1098	1205604	33.136	10.317
1049	1100401	32.388	10.160	1099	1207801	33.151	10.320
1050	**1102500**	**32.404**	**10.164**	**1100**	**1210000**	**33.166**	**10.323**

LOGARITHMS OF NUMBERS.—100 to 1000—Table 28

No. 100, Log. 2.000000 to No. 249, Log. 2.396199

No.	Log.	Diff.	No.	Log.	Diff.	No.	Log.	Diff.
100	000000	432	150	176091	289	200	301030	217
101	004321	428	151	178977	287	201	303196	216
102	008600	424	152	181844	285	202	305351	215
103	012837	420	153	184691	283	203	307496	213
104	017033	416	154	187521	281	204	309630	212
105	021189	412	155	190332	279	205	311754	211
106	025306	408	156	193125	278	206	313867	210
107	029384	404	157	195900	276	207	315970	209
108	033424	400	158	198657	274	208	318063	208
109	037426	397	159	201397	272	209	320146	207
110	041393	393	160	204120	271	210	322219	206
111	045323	389	161	206826	269	211	324282	205
112	049218	386	162	209515	267	212	326336	204
113	053078	383	163	212188	266	213	328380	203
114	056905	379	164	214844	264	214	330414	202
115	060698	376	165	217484	262	215	332438	202
116	064458	373	166	220108	261	216	334454	201
117	068186	370	167	222716	259	217	336460	199
118	071882	366	168	225309	258	218	338456	199
119	075547	363	169	227887	256	219	340444	198
120	079181	360	170	230449	255	220	342423	197
121	082785	357	171	232996	253	221	344392	196
122	086360	355	172	235528	252	222	346353	195
123	089905	352	173	238046	250	223	348305	194
124	093422	349	174	240549	249	224	350248	193
125	096910	346	175	243038	248	225	352183	193
126	100371	343	176	245513	246	226	354108	192
127	103804	341	177	247973	245	227	356026	191
128	107210	338	178	250420	243	228	357935	190
129	110590	335	179	252853	242	229	359835	189
130	113943	333	180	255273	241	230	361728	188
131	117271	330	181	257679	239	231	363612	188
132	120574	328	182	260071	238	232	365488	187
133	123852	325	183	262451	237	233	367356	186
134	127105	323	184	264818	235	234	369216	185
135	130334	321	185	267172	234	235	371068	184
136	133539	318	186	269513	233	236	372912	184
137	136721	316	187	271842	232	237	374748	183
138	139879	314	188	274158	230	238	376577	182
139	143015	311	189	276462	229	239	378398	181
140	146128	309	190	278754	228	240	380211	181
141	149219	307	191	281033	227	241	382017	180
142	152288	305	192	283301	226	242	383815	179
143	155336	303	193	285557	225	243	385606	178
144	158362	301	194	287802	223	244	387390	178
145	161368	299	195	290035	222	245	389166	177
146	164353	296	196	292256	221	246	390935	176
147	167317	295	197	294466	220	247	392697	176
148	170262	292	198	296665	219	248	394452	175
149	173186	291	199	298853	218	249	396199	174

The Logs. in the Table are decimals; the Index is one less than the figures of the number; the Log., therefore, in the Table, stands for any number—thus, Log. of 12 = 1.079181 Log. of 120 = 2.079181 Log. f 1200 = 3.079181.

LOGARITHMS OF NUMBERS.—100 to 1000—Table 28

No. 250, Log. 2.379940 to No. 399, Log. 2.600973

No.	Log.	Diff.	No.	Log.	Diff.	No.	Log.	Diff.
250	397940	173	300	477121	145	350	544068	124
251	399674	173	301	478566	144	351	545307	124
252	401401	172	302	480007	144	352	546543	123
253	403121	171	303	481443	143	353	547775	123
254	404834	171	304	482874	143	354	549003	123
255	406540	170	305	484300	142	355	550228	122
256	408240	169	306	485721	142	356	551450	122
257	409933	169	307	487138	141	357	552668	121
258	411620	168	308	488551	141	358	553883	121
259	413300	167	309	489958	140	359	555094	121
260	414973	167	310	491362	140	360	556303	120
261	416641	166	311	492760	139	361	557507	120
262	418301	165	312	494155	139	362	558709	120
263	419956	165	313	495544	139	363	559907	119
264	421604	164	314	496930	138	364	561101	119
265	423246	164	315	498311	138	365	562293	119
266	424882	163	316	499687	137	366	563481	119
267	426511	162	317	501095	137	367	564666	118
268	428135	162	318	502427	136	368	565848	118
269	429752	161	319	503791	136	369	567026	118
270	431364	161	320	505150	136	370	568202	117
271	432969	160	321	506505	135	371	569374	117
272	434569	159	322	507856	135	372	570543	117
273	436163	159	323	509203	134	373	571709	116
274	437751	158	324	510545	134	374	572872	116
275	439333	158	325	511883	133	375	574031	116
276	440909	157	326	513218	133	376	575188	115
277	442480	157	327	514548	132	377	576341	115
278	444045	156	328	515874	132	378	577492	115
279	445604	155	329	517196	132	379	578639	114
280	447158	155	330	518514	131	380	579784	114
281	448706	154	331	519828	131	381	580925	114
282	450249	154	332	521138	131	382	582063	114
283	451786	153	333	522444	130	383	583199	113
284	453318	153	334	523746	130	384	584331	113
285	454845	152	335	525045	129	385	585461	113
286	456366	152	336	526339	129	386	586587	112
287	457882	151	337	527630	129	387	587711	112
288	459392	151	338	528917	128	388	588832	112
289	460898	150	339	530200	128	389	589950	112
290	462398	140	340	531479	128	390	591065	111
291	463893	149	341	532754	127	391	592177	111
292	465383	149	342	534026	127	392	593286	111
293	466868	148	343	535294	126	393	594393	110
294	468347	148	344	536558	126	394	595496	110
295	469822	147	345	537819	126	395	596597	110
296	471292	146	346	539076	125	396	597695	110
297	472756	146	347	540329	125	397	598791	109
298	474216	146	348	541579	125	398	599883	109
299	475671	145	349	542825	124	399	600973	109

LOGARITHMS OF NUMBERS.—100 to 1000—TABLE 28

No. 400, Log. 2.602060 to No. 549, Log. 2.739572

No.	Log.	Diff.	No.	Log.	Diff.	No.	Log.	Diff.
400	602060	108	450	653213	96	500	698970	87
401	603144	108	451	654177	96	501	699838	87
402	604226	108	452	655138	96	502	700704	86
403	605305	108	453	656098	96	503	701568	86
404	606381	107	454	657056	96	504	702431	86
405	607455	107	455	658011	95	505	703291	86
406	608526	107	456	658965	95	506	704151	86
407	609594	107	457	659916	95	507	705008	86
408	610660	106	458	660865	95	508	705864	85
409	611723	106	459	661813	95	509	706718	85
410	612784	106	460	662758	94	510	707570	85
411	613842	106	461	663701	94	511	708421	85
412	614897	105	462	664642	94	512	709270	85
413	615950	105	463	665581	94	513	710117	85
414	617000	105	464	666518	94	514	710963	84
415	618048	105	465	667453	93	515	711807	84
416	619093	104	466	668386	93	516	712650	84
417	620136	104	467	669317	93	517	713491	84
418	621176	104	468	670246	93	518	714330	84
419	622214	104	469	671173	93	519	715167	84
420	623249	103	470	672098	92	520	716003	83
421	624282	103	471	673021	92	521	716838	83
422	625312	103	472	673942	92	522	717671	83
423	626340	103	473	674861	92	523	718502	83
424	627366	102	474	675778	92	524	719331	83
425	628389	102	475	676694	91	525	720159	83
426	629410	102	476	677607	91	526	720986	82
427	630428	102	477	678518	91	527	721811	82
428	631444	101	478	679428	91	528	722634	82
429	632457	101	479	680336	91	529	723456	82
430	633468	101	480	681241	90	530	724276	82
431	634477	101	481	682145	90	531	725095	82
432	635484	100	482	683047	90	532	725912	82
433	636488	100	483	683947	90	533	726727	81
434	637490	100	484	684845	90	534	727541	81
435	638489	100	485	685742	89	535	728354	81
436	639486	99	486	686636	89	536	729165	81
437	640481	99	487	687529	89	537	729974	81
438	641474	99	488	688420	89	538	730782	81
439	642465	99	489	689309	89	539	731589	81
440	643453	98	490	690196	89	540	732394	80
441	644439	98	491	691081	88	541	733197	80
442	645422	98	492	691965	88	542	733999	80
443	646404	98	493	692847	88	543	734800	80
444	647383	98	494	693727	88	544	735599	80
445	648360	97	495	694605	88	545	736397	80
446	649335	97	496	695482	87	546	737193	79
447	650308	97	497	696356	87	547	737987	79
448	651278	97	498	697229	87	548	738781	79
449	652246	97	499	698101	87	549	739572	79

No. 550, Log. 2.740363 to No. 699, Log. 2.844477

No.	Log.	Diff.	No.	Log.	Diff.	No.	Log.	Diff.
550	740363	79	600	778151	72	650	812913	67
551	741152	79	601	778874	72	651	813581	67
552	741939	79	602	779596	72	652	814248	67
553	742725	78	603	780317	72	653	814913	66
554	743510	78	604	781037	72	654	815578	66
555	744293	78	605	781755	72	655	816241	66
556	745075	78	606	782473	72	656	816904	66
557	745855	78	607	783189	71	657	817565	66
558	746634	78	608	783904	71	658	818226	66
559	747412	78	609	784617	71	659	818885	66
560	748188	77	610	785330	71	660	819544	66
561	748963	77	611	786041	71	661	820201	66
562	749736	77	612	786751	71	662	820858	66
563	750508	77	613	787460	71	663	821514	65
564	751279	77	614	788168	71	664	822168	65
565	752048	77	615	788875	71	665	822822	65
566	752816	77	616	789581	70	666	823474	65
567	753583	77	617	790285	70	667	824126	65
568	754348	76	618	790988	70	668	824776	65
569	755112	76	619	791691	70	669	825426	65
570	755875	76	620	792392	70	670	826075	65
571	756636	76	621	793092	70	671	826723	65
572	757396	76	622	793790	70	672	827369	65
573	758155	76	623	794488	70	673	828015	64
574	758912	76	624	795185	70	674	828660	64
575	759668	75	625	795880	69	675	829304	64
576	760422	75	626	796574	69	676	829947	64
577	761176	75	627	797268	69	677	830589	64
578	761928	75	628	797960	69	678	831230	64
579	762679	75	629	798651	69	679	831870	64
580	763428	75	630	799341	69	680	832509	64
581	764176	75	631	800029	69	681	833147	64
582	764923	75	632	800717	69	682	833784	64
583	765669	74	633	801404	69	683	834421	64
584	766413	74	634	802089	69	684	835056	63
585	767156	74	635	802774	68	685	835691	63
586	767898	74	636	803457	68	686	836324	63
587	768638	74	637	804139	68	687	836957	63
588	769377	74	638	804821	68	688	837588	63
589	770115	74	639	805501	68	689	838219	63
590	770852	74	640	806180	68	690	838849	63
591	771587	73	641	806858	68	691	839478	63
592	772322	73	642	807535	68	692	840106	63
593	773055	73	643	808211	67	693	840733	63
594	773786	73	644	808886	67	694	841359	63
595	774517	73	645	809560	67	695	841985	62
596	775246	73	646	810233	67	696	842609	62
597	775974	73	647	810904	67	697	843233	62
598	776701	73	648	811575	67	698	843855	62
599	777427	72	649	812245	67	699	844477	62

LOGARITHMS OF NUMBERS.—100 to 1000—TABLE 28

No. 700, Log 2.845098 to No. 849, Log 2.928908

No.	Log.	Diff.	No.	Log.	Diff.	No.	Log.	Diff.
700	845098	62	750	875061	58	800	903090	54
701	845718	62	751	875640	58	801	903633	54
702	846337	62	752	876218	58	802	904174	54
703	846955	62	753	876795	58	803	904716	54
704	847573	62	754	877371	58	804	905256	54
705	848189	62	755	877947	57	805	905796	54
706	848805	61	756	878522	57	806	906335	54
707	849419	61	757	879096	57	807	906874	54
708	850033	61	758	879669	57	808	907411	54
709	850646	61	759	880242	57	809	907949	54
710	851258	61	760	880814	57	810	908485	54
721	851870	61	761	881385	57	811	909021	54
712	852480	61	762	881955	57	812	909556	53
713	853090	61	763	882525	57	813	910091	53
714	853698	61	764	883093	57	814	910624	53
715	853306	61	765	883661	57	815	911158	53
716	854913	61	766	884229	57	816	911690	53
717	855519	61	767	884795	57	817	912222	53
718	856124	60	768	885361	57	818	912753	53
719	856729	60	769	885926	56	819	913284	53
720	857332	60	770	886491	56	820	913814	53
721	857935	60	771	887054	56	821	914343	53
722	858537	60	772	887617	56	822	914872	53
723	859138	60	773	888179	56	823	915400	53
724	859739	60	774	888741	56	824	915927	53
725	860338	60	775	889302	56	825	916454	53
726	860937	60	776	889862	56	826	916980	53
727	861534	60	777	890421	56	827	917506	52
728	862131	60	778	890980	56	828	918030	52
729	862728	60	779	891537	56	829	918555	52
730	863323	59	780	892095	56	830	919078	52
731	863917	59	781	892651	56	831	919601	52
732	864511	59	782	893207	56	832	920123	52
733	865104	59	783	893762	55	833	920645	52
734	865696	59	784	894316	55	834	921166	52
735	866287	59	785	894870	55	835	921686	52
736	866878	59	786	895423	55	836	922206	52
737	867467	59	787	895975	55	837	922725	52
738	868056	59	788	896526	55	838	923244	52
739	868644	59	789	897077	55	839	923762	52
740	869232	59	790	897627	55	840	924279	52
741	869818	59	791	898176	55	841	924796	52
742	870404	58	792	898725	55	842	925312	52
743	870989	58	793	899273	55	843	925828	51
744	871573	58	794	899821	55	844	926342	51
745	872156	58	795	900367	55	845	926857	51
746	872739	58	796	900913	55	846	927370	51
747	873321	58	797	901458	54	847	927883	51
748	873902	58	798	902003	54	848	928396	51
749	874482	58	799	902547	54	849	928908	51

LOGARITHMS OF NUMBERS.—100 to 1000—TABLE 28

No. 850, Log 2.929419 to No. 999, Log 2.999565

No.	Log.	Diff.	No.	Log.	Diff.	No.	Log.	Diff.
850	929419	51	900	954243	48	950	977724	46
851	929930	51	901	954725	48	951	978181	46
852	930440	51	902	955207	48	952	978637	46
853	930949	51	903	955688	48	953	979093	46
854	931458	51	904	956168	48	954	979548	46
855	931966	51	905	956649	48	955	980003	45
856	932474	51	906	957128	48	956	980458	45
857	932981	51	907	957607	48	957	980912	45
858	933487	51	908	958086	48	958	981366	45
859	933993	51	909	958564	48	959	981819	45
860	934498	50	910	959041	48	960	982271	45
861	935003	50	911	959518	48	961	982723	45
862	935507	50	912	959995	48	962	983175	45
863	936011	50	913	960471	48	963	983626	45
864	936514	50	914	960946	47	964	984077	45
865	937016	50	915	961421	47	965	984527	45
866	937518	50	916	961895	47	966	984977	45
867	938019	50	917	962369	47	967	985426	45
868	938520	50	918	962843	47	968	985875	45
869	939020	50	919	963316	47	969	986324	45
870	939519	50	920	963788	47	970	986772	45
871	940018	50	921	964260	47	971	987219	45
872	940516	50	922	964731	47	972	987666	45
873	941014	50	923	965202	47	973	988113	45
874	941511	50	924	965672	47	974	988559	45
875	942008	50	925	966142	47	975	989005	45
876	942504	50	926	966611	47	976	989450	44
877	943000	49	927	967080	47	977	989895	44
878	943495	49	928	967548	47	978	990339	44
879	943989	49	929	968016	47	979	990783	44
880	944483	49	930	968483	47	980	991226	44
881	944976	49	931	968950	47	981	991669	44
882	945469	49	932	969416	47	982	992111	44
883	945961	49	933	969882	47	983	992554	44
884	946452	49	934	970347	46	984	992995	44
885	946943	49	935	970812	46	985	993436	44
886	947434	49	936	971276	46	986	993877	44
887	947924	49	937	971740	46	987	994317	44
888	948413	49	938	972203	46	988	994757	44
889	948902	49	939	972666	46	989	995196	44
890	949390	49	940	973128	46	990	995635	44
891	949878	49	941	973590	46	991	996074	44
892	950365	49	942	974051	46	992	996512	44
893	950851	49	943	974512	46	993	996949	44
894	951338	49	944	974972	46	994	997386	44
895	951823	48	945	975432	46	995	997823	44
896	952308	48	946	975891	46	996	998259	44
897	952792	48	947	976350	46	997	998695	44
898	953276	48	948	976808	46	998	999131	44
899	953760	48	949	977266	46	999	999565	43

LOGARITHMIC SINES AND COSINES.—TABLE 29

SINES 0° to 45° 50′, for each 10 minutes.

Degs.	0′	10′	20′	30′	40′	50′	Degs.
0		7.463726	7.764754	7.940842	8.065776	8.162681	89
1	8.241855	8.308794	8.366777	8.417919	.463665	.505045	88
2	.542819	.577566	.609734	.639680	.667689	.693998	87
3	.718800	.742259	.764511	.785675	.805852	.825130	86
4	.843585	.861283	.878285	.894643	.910404	.925609	85
5	.940296	.954499	.968249	981573	.994497	9.007044	84
6	9.019235	9.031089	9.042625	9.053859	9.064806	.075480	83
7	.085894	.096062	.105992	.115698	.125187	134470	82
8	.143555	.152451	.161164	.169702	.178072	.186280	81
9	.194332	.202234	.209992	.217609	.225092	.232444	80
10	.239670	.246775	.253761	.260633	.267395	.274049	79
11	.280599	.287048	.293399	.299655	.305819	.311893	78
12	.317879	.323780	.329599	.335337	.340996	.346579	77
13	.352088	.357524	.362889	.368185	.373414	.378577	76
14	.383675	.388711	.393685	.398600	.403455	.408254	75
15	.412996	.417684	.422318	.426899	.431429	.435908	74
16	.440338	.444720	.449054	.453342	.457584	.461782	73
17	.465935	.470046	.474115	.478142	.482128	.486075	72
18	.489982	.493851	.497682	.501476	.505234	.508956	71
19	.512642	.516294	.519911	.523495	.527046	.530565	70
20	.534052	.537507	.540931	.544325	.547689	.551024	69
21	.554329	.557606	.560855	.564075	.567269	.570435	68
22	.573575	.576689	.579777	.582840	.585877	.588890	67
23	.591878	.594842	.597783	.600700	.603594	.606465	66
24	.609313	.612140	.614944	.617727	.620488	.623229	65
25	.625948	.628647	.631326	.633984	.636623	.639242	64
26	.641842	.644423	.646984	.649527	.652052	.654558	63
27	.657047	.659517	.661970	.664406	.666824	.669225	62
28	.671609	.673977	.676328	.678663	.680982	.683284	61
29	.685571	.687843	.690098	.692339	.694564	.696775	60
30	.698970	.701151	.703317	.705469	.707606	.709730	59
31	.711839	713935	.716017	.718085	.720140	.722181	58
32	.724210	.726225	.728227	.730217	.732193	.734157	57
33	.736109	.738048	.739975	.741889	.743792	.745683	56
34	.747562	.749429	.751284	.753128	.754960	.756782	55
35	.758591	.760390	.762177	.763954	.765720	.767475	54
36	.769219	.770952	.772675	.774388	.776090	.777781	53
37	.779463	.781134	.782796	.784447	.786089	.787720	52
38	.789342	.790954	.792557	.794150	.795733	.797307	51
39	.798872	.800427	.801973	.803511	.805039	.806557	50
40	.808067	.809569	.811061	.812544	.814019	.815485	49
41	.816943	.818392	.819832	.821265	.822688	.824104	48
42	.825511	.826910	.828301	.829683	.831058	.832425	47
43	.833783	.835134	.836477	.837812	.839140	.840459	46
44	.841771	.843076	.844372	.845662	.846944	.848218	45
45	.849485	.850745	.851997	.853242	.854480	.855711	44
Degs.	60′	50′	40′	30′	20′	10′	Degs.

COSINES 44° 10′ to 90°, for each 10 minutes.

LOGARITHMIC SINES AND COSINES.—TABLE 29

SINES 46° to 90°, for each 10 minutes.

Degs.	0′	10′	20′	30′	40′	50′	Degs.
46	9.856934	9.858151	9.859360	9.860562	9.861758	9.862946	43
47	.864127	.865302	.866470	.867631	.868785	.869933	42
48	.871073	.872208	.873335	.874456	.875571	.876678	41
49	.877780	.878875	.979963	.881046	.882121	.883191	40
50	.884254	.885311	.886362	.887406	.888444	.889477	39
51	.890503	.891523	.892536	.893544	.894546	.895542	38
52	.896532	.897516	.898494	.899467	.900433	.901394	37
53	.902349	.903298	.904241	.905179	.906111	.907037	36
54	.907958	.908873	.909782	.910686	.911584	.912477	35
55	.913365	.914246	.915123	.915994	.916859	.917719	34
56	.918574	.919424	.920268	.921107	.921940	.922768	33
57	.923591	.924409	.925222	.926029	926831	.927629	32
58	.928420	.929207	.929989	.930766	.931537	.932304	31
59	.933066	.933822	.934574	.935320	.936062	.936799	30
60	.937531	.938258	.938980	.939697	.940409	.941117	29
61	.941819	.942517	.943210	.943899	.944582	.945261	28
62	.945935	.946604	.947269	.947929	.948584	.949235	27
63	.949881	.950522	.951159	.951791	.952419	.953042	26
64	.953660	.954274	.954883	.955488	.956089	.956684	25
65	.957276	.957863	.958445	.959023	.959596	.960165	24
66	.960730	.961290	.961846	.962398	.962945	.963488	23
67	.964026	.964560	.965090	.965615	.966136	.966653	22
68	.967166	.967674	.968178	.968678	.969173	.969665	21
69	.970152	.970635	.971113	.971588	.972058	.972524	20
70	.972986	.973444	.973897	.974347	.974792	.975233	19
71	.975670	.976103	.976532	.976957	.977377	.977794	18
72	.978206	.978615	.979019	.979420	.979816	.980208	17
73	.980596	.980981	.981361	.981737	.982109	.982477	16
74	.982842	.983202	.983558	.983911	.984259	.984603	15
75	.984944	.985280	.985613	.985942	.986266	.986587	14
76	.986904	.987217	.987526	.987832	.988133	.988430	13
77	.988724	.989014	.989300	.989582	.989860	.990134	12
78	.990404	.990671	.990934	.991193	.991448	.991699	11
79	.991947	.992190	.992430	.992666	.992898	.993127	10
80	.993351	.993572	.993789	.994003	.994212	.994418	9
81	.994620	.994818	.995013	.995203	.995390	.995573	8
82	.995753	.995928	.996100	.996269	.996433	.996594	7
83	.996751	.996904	.997053	.997199	.997341	.997480	6
84	.997614	.997745	.997872	.997996	.998116	.998232	5
85	.998344	.998453	.998558	.998659	.998757	.998851	4
86	.998941	.999027	.999110	.999189	.999265	.999336	3
87	.999404	.999469	.999529	.999586	.999640	.999689	2
88	.999735	.999778	.999816	.999851	.999882	.999910	1
89	.999934	.999954	.999971	.999983	.999993	.999998	0
90	10.000000	......	......	......	......	......	...
Degs.	60′	50′	40′	30′	20′	10′	Degs.

COSINES 0° to 44°, for each 10 minutes.

TRIGONOMETRIC RATIOS.—Table 30.

NATURAL SINES, TANGENTS, AND SECANTS,

WITH THEIR COSINES, COTANGENTS, AND COSECANTS,

To every degree of the Quadrant, radius being 1.000000.

Note.—From 0 to 45 degrees the name of the column is at the head of the page; from 45 to 90 degrees the name of the column is at the foot of the page.

Arc.	Sine.	Cosine.	Tangent.	Cotan.	Secant.	Cosec.	Arc.
0°	.000000	1.000000	.000000	Infinite.	1.000000	Infinite.	90°
1	.017452	.999848	.017455	57.28996	1.000152	57.29869	89
2	.034899	.999391	.034921	28.63625	1.000609	28.65371	88
3	.052336	.998630	.052408	19.08114	1.001372	19.10732	87
4	.069756	.997564	.069927	14.30066	1.002442	14.33559	86
5	.087156	.996195	.087489	11.43005	1.003820	11.47371	85
6	.104528	.994522	.105104	9.514365	1.005508	9.566772	84
7	.121869	.992546	.122784	8.144346	1.007510	8.205509	83
8	.139173	.990278	.140541	7.115370	1.009828	7.185297	82
9	.156434	.987688	.158384	6.313752	1.012465	6.392453	81
10	.173648	.984808	.176327	5.671282	1.015427	5.758771	80
11	.190809	.981627	.194380	5.144554	1.018717	5.240843	79
12	.207912	.978148	.212557	4.704630	1.022341	4.809734	78
13	.224951	.974370	.230868	4.331476	1.026304	4.445411	77
14	.241922	.970296	.249328	4.010781	1.030614	4.133566	76
15	.258819	.965926	.267949	3.732051	1.035276	3.863703	75
16	.275637	.961262	.286745	3.487414	1.040299	3.627955	74
17	.292372	.956305	.305731	3.270853	1.045692	3.420304	73
18	.309017	.951056	.324920	3.077684	1.051462	3.236068	72
19	.325568	.945519	.344328	2.904211	1.057621	3.071554	71
20	.342020	.939693	.363970	2.747477	1.064178	2.923804	70
21	.358368	.933580	.383864	2.605089	1.071145	2.790428	69
22	.374607	.927184	.404026	2.475087	1.078535	2.669467	68
23	.390731	.920505	.424475	2.355852	1.086360	2.559305	67
24	.406737	.913546	.445229	2.246037	1.094636	2.458593	66
25	.422618	.906308	.466308	2.144507	1.103378	2.366202	65
26	.438371	.898794	.487733	2.050304	1.112602	2.281172	64
27	.453991	.891007	.509525	1.962611	1.122326	2.202689	63
28	.469472	.882948	.531709	1.880727	1.132570	2.130045	62
29	.484810	.874620	.554309	1.804048	1.143354	2.062665	61
30	.500000	.866025	.577350	1.732051	1.154701	2.000000	60
31	.515038	.857167	.600861	1.664280	1.166633	1.941604	59
32	.529919	.848048	.624869	1.600335	1.179178	1.887080	58
33	.544639	.838671	.649408	1.539865	1.192363	1.836079	57
34	.559193	.829038	.674509	1.482561	1.206218	1.788292	56
35	.573576	.819152	.700208	1.428148	1.220775	1.743447	55
36	.587785	.809017	.726543	1.376382	1.236068	1.701302	54
37	.601815	.798636	.753544	1.327045	1.252136	1.661640	53
38	.615661	.788011	.781286	1.279942	1.269018	1.624269	52
39	.629320	.777146	.809784	1.234897	1.286760	1.589016	51
40	.642788	.766044	.839100	1.191754	1.305407	1.555724	50
41	.656059	.754710	.869287	1.150368	1.325013	1.524253	49
42	.669131	.743145	.900404	1.110613	1.345633	1.494477	48
43	.681998	.731354	.932515	1.072369	1.367328	1.466279	47
44	.694658	.719340	.965689	1.035530	1.390164	1.439557	46
45	.707107	.707107	1.000000	1.000000	1.414214	1.414214	45
Arc.	Cosine.	Sine.	Cotan.	Tangent.	Cosec.	Secant.	Arc.

ANNUITIES AND LEASES.

TABLES 31, 31a, and 31b.

Abstracted from Weale's Edition of Inwood's Tables.

D

TABLE FOR FINDING VALUE

OF

ANNUITIES AND LEASES, HELD FOR A CERTAIN TERM.

Rule.—The tabular number in the column of the estimated rate of interest, opposite the number of years the lease is to continue, multiplied by the annual rental, will give the value.

For Freeholds, take the number in the line marked "Perp.," from the column of the estimated rate of interest.

Years of Lease, Ann., &c.	YEARS' PURCHASE.							
	3 ℔ Cent.	4 ℔ Cent.	5 ℔ Cent.	6 ℔ Cent.	7 ℔ Cent.	8 ℔ Cent.	9 ℔ Cent.	10 ℔ Cent.
5	4.58	4.45	4.33	4.21	4.10	3.99	3.89	3.79
10	8.53	8.11	7.72	7.36	7.02	6.71	6.42	6.14
15	11.94	11.12	10.38	9.71	9.11	8.56	8.06	7.61
20	14.88	13.59	12.46	11.47	10.59	9.82	9.13	8.51
21	15.42	14.03	12.82	11.76	10.84	10.02	9.29	8.65
22	15.94	14.45	13.16	12.04	11.06	10.20	9.44	8.77
23	16.44	14.86	13.49	12.30	11.27	10.37	9.58	8.88
24	16.94	15.25	13.80	12.55	11.47	10.53	9.71	8.99
25	17.41	15.62	14.09	12.78	11.65	10.67	9.82	9.08
26	17.88	15.98	14.38	13.00	11.83	10.81	9.93	9.16
27	18.33	16.33	14.64	13.21	11.99	10.94	10.03	9.24
28	18.76	16.66	14.90	13.41	12.14	11.05	10.12	9.31
29	19.19	16.98	15.14	13.59	12.28	11.16	10.20	9.37
30	19.60	17.29	15.37	13.77	12.41	11.26	10.27	9.43
31	20.00	17.59	15.59	13.93	12.53	11.35	10.34	9.48
32	20.39	17.87	15.80	14.08	12.65	11.43	10.41	9.53
33	20.77	18.15	16.00	14.23	12.75	11.51	10 46	9.57
34	21.13	18.41	16.19	14.37	12.85	11.59	10.52	9.61
35	21.49	18.67	16.37	14.50	12.95	11.65	10.57	9.64
36	21.83	18 91	16.55	14.62	13.04	11.72	10.61	9.68
37	22.17	19.14	16.71	14.74	13.12	11.78	10.65	9.71
38	22.49	19.37	16.87	14.85	13.19	11.83	10.69	9.73
39	22.80	19.58	17.02	14.95	13.26	11.88	10.73	9.76
40	23 12	19.79	17.16	15.05	13.33	11.93	10.76	9.78
45	24.52	20.72	17.77	15.46	13.61	12.11	10.88	9.86
50	25.73	21.48	18.26	15.76	13.80	12.23	10.96	9.92
55	26.77	22.11	18.63	15.99	13.94	12.32	11.01	9.95
60	27.68	22.62	18.93	16.16	14.04	12.38	11.05	9.97
70	29.12	23.40	19.34	16.39	14.16	12.44	11.08	9.99
80	30.20	23.92	19.60	16.51	14.22	12.47	11.10	10.00
90	31.00	24.27	19 75	16.58	14.25	12.49	11.11	10.00
100	31.60	24.51	19.85	16.62	14.27	12.49	11.11	10.00
Perp.	33.33	25.00	20.00	16.67	14.29	12.50	11.11	10.00

TABLE FOR FINDING VALUE

OF

ANNUITIES AND LEASES, HELD FOR A SINGLE LIFE.

Rule.—The tabular number in the column of the estimated rate of interest, opposite the age of the life in the first column, multiplied by the annual rental, will give the value.

Years of Age.	YEARS' PURCHASE.					
	3 ℔ Cent.	4 ℔ Cent.	5 ℔ Cent.	6 ℔ Cent.	7 ℔ Cent.	8 ℔ Cent.
10	20.66	17.52	15.14	13.28	11.81	10.61
15	19.66	16.79	14.59	12.86	11.47	10.34
16	19.44	16.63	14.46	12.76	11.38	10.27
17	19.22	16.46	14.33	12.66	11.30	10.20
18	19.01	16.31	14.22	12.56	11.23	10.14
19	18.82	16.17	14.11	12.48	11.16	10.08
20	18.64	16.03	14.01	12.40	11.09	10.03
21	18.47	15.91	13.92	12.33	11.04	9.99
22	18.31	15.80	13.83	12.27	10.99	9.95
23	18.15	15.68	13.75	12.20	10.94	9.91
24	17.98	15.56	13.66	12.13	10.89	9.87
25	17.81	15.44	13.57	12.06	10.84	9.82
26	17.64	15.31	13.47	11.99	10.78	9.78
27	17.47	15.18	13.38	11.92	10.72	9.73
28	17.29	15.05	13.28	11.84	10.66	9 69
29	17.11	14.92	13.18	11.76	10.60	9.64
30	16.92	14.78	13.07	11.68	10.54	9.58
31	16.73	14.64	12.97	11.60	10.47	9.53
32	16.54	14.50	12.85	11.51	10.40	9.48
33	16.34	14.35	12.74	11.42	10.33	9.42
34	16.14	14.20	12.62	11.33	10.26	9.36
35	15.94	14.04	12.50	11.24	10.18	9.30
36	15.73	13.88	12.38	11.14	10.10	9.23
37	15.52	13.72	12.25	11.04	10.02	9.16
38	15.30	13.55	12.12	10.93	9.94	9.09
39	15.08	13.38	11.98	10.82	9.85	9.02
40	14.85	13.20	11.84	10.71	9.75	8.94
45	13.69	12.28	11.11	10.11	9.26	8.53
50	12.44	11.26	10.27	9.42	8.68	8.04
55	11.15	10.20	9.38	8.67	8.05	7.50
60	9.78	9.04	8.39	7.82	7.31	6.86
70	6.73	6.36	6.02	5.72	5.43	5.18
80	3.78	3.64	3.52	3.39	3.28	3.17
90	1.79	1.76	1.72	1.69	1.66	1.63

ANNUITIES AND LEASES.—Table 31b.

TABLE SHEWING PRESENT VALUE OF A REVERSION IN PERPETUITY,

AFTER ANY GIVEN TERM, FROM 10 TO 60 YEARS,

At Rates of Interest from 3 to 8 per Cent.

Rule.—The tabular number in the column of the estimated rate of interest, opposite the number of years to run, multiplied by the rental, will give the value.

Years to Run.	Years' Purchase at 3 ℘ Cent.	Years' Purchase at 4 ℘ Cent.	Years' Purchase at 5 ℘ Cent.	Years' Purchase at 6 ℘ Cent.	Years' Purchase at 7 ℘ Cent.	Years' Purchase at 8 ℘ Cent.	Years' Purchase at 10 ℘ Cent.
10	24.80	16.89	12.28	9.31	7.26	5.79	3.85
12	23.38	15.61	11.14	8.28	6.34	4.96	3.17
14	22.04	14.44	10.10	7.37	5.54	4.26	2.63
16	20.77	13.35	9.16	6.56	4.84	3.65	2.18
18	19.58	12.34	8.31	5.84	4.23	3.13	1.80
20	18.46	11.41	7.54	5.20	3.69	2.68	1.48
22	17.40	10.55	6.84	4.62	3.22	2.30	1.23
24	16.40	9.75	6.20	4.12	2.82	1.97	1.01
26	15.46	9.02	5.62	3.66	2.46	1.69	.84
28	14.57	8.34	5.10	3.26	2.15	1.45	.69
30	13.73	7.71	4.62	2.90	1.88	1.24	.57
32	12.94	7.13	4.20	2.58	1.64	1.06	.47
34	12.20	6.59	3.81	2.30	1.43	.91	.39
36	11.50	6.09	3.45	2.05	1.25	.78	.32
38	10.84	5.63	3.13	1.82	1.09	.67	.27
40	10.22	5.21	2.84	1.62	.95	.57	.22
42	9.63	4.81	2.58	1.44	.83	.49	.18
44	9.08	4.45	2.34	1.28	.73	.42	.15
46	8.55	4.11	2.12	1.14	.63	.36	.12
48	8.07	3.80	1.92	1.02	.55	.31	.10
50	7.60	3.52	1.74	.90	.48	.27	.08
52	7.17	3.25	1.58	.81	.42	.23	.07
54	6.76	3.01	1.43	.72	.37	.20	.06
56	6.37	2.78	1.30	.64	.32	.17	.05
58	6.00	2.57	1.18	.57	.28	.14	.04
60	5.66	2.38	1.07	.51	.25	.12	.03

Table 31c.

SHEWING THE VALUE OF AN ANNUITY OF £100,

ON A SINGLE LIFE FROM 10 TO 90 YEARS OF AGE.

As Fixed by the Legacy Act.

Age.	Value. £	s.	Age.	Value. £	s.	Age.	Value. £	s.	Age.	Value. £	s.
10	1,752	6	30	1,478	2	50	1,126	8	70	636	2
15	1,679	2	35	1,403	18	55	1,020	2	75	496	4
20	1,603	6	40	1,319	14	60	903	18	80	364	6
25	1,543	16	45	1,228	6	65	776	2	90	175	16

TIDES OF BRITISH PORTS,

AND

TIDE TABLES;

WITH THE

MOON'S TRANSIT AND HORIZONTAL PARALLAX

FOR 1852, 1853, AND 1854.

TABLES 32, 32a, 32b, 32c, 33, 34, and 35.

DESCRIPTION OF TABLES 32, 32a, 32b, 33, 34 & 35.

These tables, which are chiefly based on the notes to the Admiralty tide tables, will be found useful, not only for finding the heights and times of high water at the various ports mentioned, but also for tracing the progress of the tidal wave, and for readily ascertaining when any particularly high or low tide may be expected, by the rise attached to the different hours of the moon's declination at noon.

Table 32 gives the constants for finding the *time* of high water at twenty places; no other corrections are given, as they are too small to affect the validity of the result; a light breeze would occasion a greater variation than the largest correction that can be applied for time, and often for heights.

Table 32a gives the constants for finding the *heights* of high water at the same twenty places; for greater accuracy, the corrections for the moon's declination and parallax given in Table 32*b* must be applied.

Table 32b gives the corrections of height for the moon's declination and parallax for twenty places, which are to be applied to the constants previously found in Table 32*a*.

Table 34 contains the moon's transit and declination at noon, for the years 1852, 1853, and 1854, from the *Nautical Almanac*. New moon and full moon occur when the transit is at 12 and 24 hours respectively.

Table 35 gives the moon's horizontal parallax at noon, for every fifth day of the month, for 1852, 1853, and 1854; the intermediate days may be averaged accurately enough for the corrections of Table 32*b*.

Tables 32 and 32*a* give the time and heights for a London tide two days following the transit, to be taken as a datum; for tides at the other specified places, take the additions shewn in Table 32. *The time in* Tables 34 and 35 *is mean solar; therefore, for reducing all the times of the tables to common time*, correction must be made from an almanac according to the season.

Example.—*Required the Time and Height of High Water at Hull, on January 24th*, 1852.

	D.	H.	M.
Moon's transit on January 22nd, at	0	1	13
Table 32 gives for 1h. 13m. at Hull	1	19	10
The time of high water following noon of Jan. 22nd	1	20	23

or 8h. 23m. a.m. *mean solar time* on January 24th.

		Feet.
The same transit gives, by Table 32*a*		20.63
Correction for declination on January 22nd, viz., 18 deg.		—.16
„ parallax „	viz., 55 min.	—.63
The height of high water, when corrected, being......		19.84

on January 24th, or 19 feet 10 ins. at 8.23 a.m.

Table 33 gives the mean spring range, and the constants of *time and heights* of high water, for a number of places, to be added or deducted, in reference to the standard places designated in black letters at the head of each division; the time and heights of these leading places being found from the tables 32, 32*a*, and 32*b*, in connection with the moon's transit, as before described. It must be recollected that whatever the tide may range on the particular day required at the standard place, yet the constant difference at any other place, referred to such standard, will be the same; the places being in fact both situate on co-tidal lines.

TIDES OF BRITISH PORTS.

EXAMPLE.—*Let it be required to find the Time and Height of High Water at Great Grimsby on the same date, viz., January 24th,* 1852.

	H.	M.	
Hull is the port of reference for Great Grimsby. The time of high water there, by the former example, is	8	23	a.m.
Constant for Great Grimsby	—0	53	
Giving for the time of high water....	7	30	a.m.
	Ft.	In.	
Height of high water at Hull on January 24th....	19	10	
Constant for Great Grimsby	—1	8	
Giving for the height of high water ..	18	2	

THE DEVONPORT TIDAL CONSTANTS, in Table 32*b*, were reduced by Dr. Whewell, from observations made at Devonport; the times being deduced from three and the heights from five years' observations.

The method of using them is very similar to that of the other tables, but in order to make it clearer, an example is given below.

To find the Time and Height of High Water at Devonport, on January 26th, 1853.

	h.	m.
Moon's transit, January 24th	12	03
Table 38 gives	6	33
Time of high water, January 26th, being .... or 6h. 36m. a.m.	18	36

To find the height,—	Feet.
The above transit gives............................	15.37
Correction for declination, 23 deg.	.35
Height of high water, January 26th, being	15.02

To find the Height of Low Water and the Range of the Tide.

The zero of heights in Tables 32 and 32a, is the mean height of low water at spring tides.

The low water of any one tide is generally as much above the *mean* low water as the high water of the same tide is below *mean* high water; and if the high water be above mean high water, the low water is as much below the zero of the tables.

EXAMPLE.—*Required the Height of Low Water and the Range of Tide at Hull, on January* 22*nd,* 1852.

	Ft.	In.
Height of high water as above.......................	20	5
Mean height of high water at spring tides, above zero..	20	10

Therefore high water at Hull, on the 22nd January, 1852, will be 5 ins. below that of mean spring tide, and low water will be 5 ins. above zero; therefore the range of the day will be 20 ft. 10 ins. — 2 × 5 = 20 feet.

To find the height of the tide at say four hours from high water of the above day, take multiplier for four hours from Table 24*b*, page 47, = .258 × 20 feet, = 5.16 feet above the low water of the day, which being 5 inches above zero of the tables, .42 is to be added to the above, making the height of the tide, at 4 hours ebb, 5.58 feet above zero of the tables. In contracted places and rivers, the tide flows faster than it ebbs, as will be seen in our various examples; this was also found to occur even throughout the Irish Sea, by Captain Beechey.

Table 32c shews the state of tide at each half-hour of rise or fall, for tides ranging from 6 to 40 feet; this will give by inspection a more accurate result than the foregoing rule.

TIDES OF BRITISH PORTS.—Table 32.

TABLE FOR COMPUTING TIME OF HIGH WATER,

For Twenty Places specified,

Showing the Semi-menstrual Inequality, + a constant; representing the Interval between the Moon's Transit, two days preceding a London Tide, and the Time of High Water; the Moon's Parallax being 57′, her Declination 15°; the Sun's Parallax 8″·8, and Declination 15°.

Moon's Transit B.	Brest.	Portsmouth.	Dover.	Sheerness.	London.	Harwich.	Hull.
	d h m	d h m	d h m	d h m	d h m	d h m	d h m
0 0	1 4 24	1 12 21	1 11 54	2 1 56	2 3 13	2 1 9	1 19 28
1 0	1 4 8	1 12 08	1 11 43	2 1 39	2 2 57	2 0 54	1 19 12
2 0	1 3 52	1 11 53	1 11 32	2 1 22	2 2 41	2 0 40	1 18 57
3 0	1 3 39	1 11 40	1 11 21	2 1 9	2 2 29	2 0 27	1 18 45
4 0	1 3 33	1 11 32	1 11 13	2 1 3	2 2 23	2 0 18	1 18 39
5 0	1 3 35	1 11 32	1 11 12	2 1 10	2 2 28	2 0 21	1 18 54
6 0	1 3 56	1 11 49	1 11 22	2 1 37	2 2 51	2 0 44	1 19 18
7 0	1 4 33	1 12 21	1 11 47	2 2 12	2 3 24	2 1 20	1 19 42
8 0	1 4 56	1 12 47	1 12 12	2 2 32	2 3 47	2 1 39	1 20 1
9 0	1 5 00	1 12 54	1 12 16	2 2 33	2 3 50	2 1 44	1 20 2
10 0	1 4 51	1 12 47	1 12 13	2 2 24	2 3 43	2 1 37	1 19 53
11 0	1 4 38	1 12 34	1 12 04	2 2 10	2 3 29	2 1 24	1 19 42

Moon's Transit B.	Sunderland.	Leith.	Thurso.	Greenock	Liverpool	Pembroke.	Weston super-Mare.
h. m.	d h m	d h m	d h m	d h m	d h m	d h m	d h m
0 0	1 16 18	1 15 15	1 9 04	1 12 48	1 12 02	1 6 51	1 7 34
1 0	1 16 02	1 15 00	1 8 50	1 12 34	1 11 46	1 6 35	1 7 18
2 0	1 15 48	1 14 47	1 8 37	1 12 18	1 11 33	1 6 20	1 7 00
3 0	1 15 38	1 14 36	1 8 28	1 12 04	1 11 22	1 6 07	1 6 42
4 0	1 15 35	1 14 34	1 8 26	1 11 55	1 11 14	1 5 55	1 6 24
5 0	1 15 42	1 14 45	1 8 35	1 11 56	1 11 17	1 5 50	1 6 17
6 0	1 16 08	1 15 13	1 9 06	1 12 15	1 11 43	1 5 58	1 6 34
7 0	1 16 36	1 15 42	1 9 43	1 12 46	1 12 15	1 6 32	1 7 07
8 0	1 16 51	1 15 58	1 9 59	1 13 09	1 12 36	1 7 03	1 7 37
9 0	1 16 55	1 15 55	1 9 54	1 13 14	1 12 40	1 7 14	1 7 54
10 0	1 16 49	1 15 47	1 9 38	1 13 10	1 12 33	1 7 14	1 7 55
11 0	1 16 34	1 15 33	1 9 21	1 13 01	1 12 20	1 7 05	1 7 47

Moon's Transit B.	Holyhead.	Kingstown.	Belfast.	Sligo.	Galway.	Queenstown.
h. m.	d h m	d h m	d h m	d h m	d h m	d h m
0 0	1 10 47	1 11 47	1 11 25	1 6 37	1 5 14	1 5 41
1 0	1 10 30	1 11 34	1 11 09	1 6 22	1 5 00	1 5 26
2 0	1 10 18	1 11 21	1 10 57	1 6 09	1 4 46	1 5 11
3 0	1 10 10	1 11 10	1 10 49	1 5 55	1 4 35	1 4 57
4 0	1 10 07	1 11 06	1 10 49	1 5 54	1 4 31	1 4 45
5 0	1 10 16	1 11 15	1 10 57	1 6 11	1 4 36	1 4 42
6 0	1 10 46	1 11 38	1 11 20	1 6 38	1 5 01	1 5 00
7 0	1 11 16	1 12 03	1 11 48	1 7 04	1 5 33	1 5 32
8 0	1 11 31	1 12 21	1 12 06	1 7 15	1 5 49	1 5 59
9 0	1 11 31	1 12 28	1 12 05	1 7 12	1 5 50	1 6 08
10 0	1 11 20	1 12 19	1 11 56	1 7 04	1 5 42	1 6 04
11 0	1 11 06	1 12 03	1 11 42	1 6 52	1 5 29	1 5 53

TIDES OF BRITISH PORTS.—Table 32a.

TABLE FOR COMPUTING HEIGHTS OF HIGH WATER,

For Twenty Places specified,

Showing the Semi-menstrual Inequality, + a constant, in the Height of High Water, with reference to the apparent Solar time of the Moon's Transit B, the Moon's Parallax being 57′, and her Declination 15°; the Sun's Parallax 8″·8, and Declination 15°.

Moon's Transit B.	Brest.	Portsmouth.	Dover.	Sheerness.	London.	Harwich.	Hull.
h. m.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0 0	19.06	12.62	18.66	16.10	19.51	11.56	20.87
1 0	18.92	12.51	18.61	15.96	19.45	11.38	20.75
2 0	18.36	12.29	18.24	15.59	19.10	11.10	20.17
3 0	17.31	11.84	17.54	14.98	18.48	10.72	19.18
4 0	15.88	11.24	16.48	14.17	17.65	10.28	18.05
5 0	14.47	10.57	15.36	13.46	16.85	9.88	16.96
6 0	13.83	10.07	14.51	13.10	16.33	9.72	16.34
7 0	14.08	10.19	14.72	13.48	16.39	9.95	16.78
8 0	15.17	10.91	15.75	14.21	17.00	10.43	18.06
9 0	16.66	11.62	16.85	14.96	17.85	10.94	19.22
10 0	18.03	12.18	17.78	15.61	18.64	11.38	20.09
11 0	18.84	12.52	18.41	16.03	19.22	11.57	20.63

Moon's Transit B.	Sunderland.	Leith.	Thurso.	Greenock	Liverpool	Pembroke.	Weston super-Mare.
h. m.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0 0	14.43	16.29	13.25	9.72	25.50	21.00	37.27
1 0	14.26	16.00	13.00	9.71	25.43	20.82	37.09
2 0	13.71	15.54	12.46	9.61	24.68	20.24	36.37
3 0	13.01	14.88	11.67	9.33	23.66	19.25	34.83
4 0	12.22	13.92	10.76	9.00	22·30	17.96	32.67
5 0	11.46	13.05	9.98	8.64	20.98	16.58	30.34
6 0	11.02	12.58	9.52	8.29	20.33	15.63	28.79
7 0	11.25	12.87	9.61	8.29	20.48	15.77	29.08
8 0	12.09	13.60	10.30	8.67	21.79	17.00	30.79
9 0	12.95	14.61	11.45	9.04	23.13	18.54	33.16
10 0	13.64	15.59	12.52	9.31	24.28	19.81	35.25
11 0	14.14	16.18	13.18	9.56	25.13	20.62	36.50

Moon's Transit B.	Holyhead.	Kingstown.	Belfast.	Sligo.	Galway.	Queenstown.
h. m.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0 0	16.00	10.94	9.43	8.54	14.83	11.75
1 0	15.83	10.80	9.37	8.45	14.68	11.69
2 0	15.41	10.49	9.24	8.06	14.20	11.37
3 0	14.68	10.05	9.00	7.51	13.43	10.84
4 0	13.84	9.61	8.63	6.83	12.34	10.19
5 0	13.03	9.13	8.30	6.22	11.30	9.55
6 0	12.63	8.83	8.09	5.98	10.87	9.14
7 0	12.97	9.10	8.07	5.94	11.17	9.26
8 0	13.66	9.55	8.36	6.35	12.02	9.78
9 0	14.55	10.04	8.86	7.25	12.98	10.47
10 0	15.30	10.50	9.22	7.96	13.82	11.12
11 0	15.80	10.86	9.41	8.31	14.49	11.57

TABLE OF CORRECTIONS FOR THE MOON'S DECLINATION AND PARALLAX,

For the Twenty Places specified.

Note.—For the Moon's Declination, no correction from 14° to 16°.
„ „ Parallax „ „ for 57.

Name of Port.	Moon's Declination.						Moons' Parallax.				
	0° to 6°+	9.°+ and 21.°—	12.°+ and 18.°—	24° —	27° —	30° —	54′ —	55′— and 59′+	56′— and 58+	60′ +	61′ +
	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
Brest	.46	.42	.19	.72	1.01	1.31	1.02	.72	.35	1.15	1.56
Portsmouth	.23	.21	.10	.36	.50	.65	.51	.36	.18	.58	.78
Dover	.38	.34	.16	.58	.82	1.07	.83	.77	.29	.86	1.26
Sheerness	.26	.23	.11	.40	.56	.73	.58	.40	.19	.64	.87
London	.29	.26	.12	.45	.63	.82	.64	.45	.22	.72	.97
Harwich	.17	.16	.07	.27	.37	.49	.38	.27	.13	.43	.58
Hull	.41	.36	.16	.63	.88	1.15	.90	.63	.31	1.01	1.36
Sunderland	.29	.26	.12	.45	.63	.82	.64	.45	.22	.72	.97
Leith	.32	.29	.13	.49	.69	.90	.70	.49	.24	.79	1.07
Thurso	.32	.29	.13	.49	.69	.90	.70	.49	.24	.79	1.07
Greenock	.14	.13	.06	.22	.31	.41	.32	.22	.11	.36	.48
Liverpool	.46	.42	.19	.72	1.01	1.31	1.02	.72	.35	1.15	1.56
Pembroke	.46	.42	.19	.72	1.01	1.31	1.02	.72	.35	1.15	1.56
Weston-super-Mare	.75	.68	.31	1.17	1.64	2.13	1.66	1.17	.57	1.77	2.53
Holyhead	.32	.29	.13	.49	.69	.90	.70	.49	.24	.79	1.07
Kingstown	.17	.16	.07	.27	.37	.49	.38	.27	.13	.43	.58
Belfast	.12	.10	.05	.18	.25	.33	.26	.18	.09	.30	.39
Sligo	.23	.21	.10	.36	.50	.65	.51	.36	.18	.58	.78
Galway	.37	.31	.14	.54	.75	.98	.77	.54	.26	.86	1.16
Queenstown (Cork)	.23	.21	.10	.36	.50	.65	.51	.36	.18	.58	.78

DEVONPORT TIDES.

Table shewing the Semi-menstrual Inequality, or the interval between the apparent Solar time of the Moon's Transit, 1½ day preceding a Devonport Tide, and the time of High Water; also the same inequality in the height of High Water, the Moon's Declination being 16° 30′, and Horizontal Parallax 57′.

Moon's Transit.	Interval.	Height.	Moon's Transit.	Interval.	Height	Moon's Transit.	Interval.	Height
H. M.	H. M.	Feet.	H. M.	H. M.	Feet.	H. M.	H. M.	Feet.
0 30	6.20	15.34	4 30	5.35	12.82	8 30	7.07	13.85
1 30	6.11	15.01	5 30	5.45	12.24	9 30	7.07	14.64
2 30	5.55	14.41	6 30	6.19	12.29	10 30	6.59	15.14
3 30	5.40	13.64	7 30	6.52	12.92	11 30	6.46	15.40

TABLE OF CORRECTIONS FOR THE MOON'S DECLINATION AND PARALLAX.

Moon's Transit.	Moon's Declination.						Moon's Parallax.				
	0° to 3°+	6° to 9°+	12°+ and 21°—	15+ and 18—	24°—	27°—	54′—	55′— and 59+	56— and 58+	60′ +	61′ +
H. M. A.M.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
0 30 to 6 0	.26	.18	.13	.04	.31	.44	.80	.54	.27	.81	1.00
6 0 to 11 30	.45	.31	.18	.05	.39	.60	.66	.45	.22	.64	.86

TIDES OF BRITISH PORTS.—Table 32c.

TABLE FOR FINDING THE HEIGHT OF THE TIDE

AT ANY INTERMEDIATE HOURS OR HALF-HOURS

BEFORE OR AFTER HIGH WATER.

The first column gives the several Ranges of Tide; the Low Water is supposed to be Zero at six hours after High Water.

Range. H. M. 6 0		H. M. 5 30		H. M. 5 0		H. M. 4 30		H. M. 4 0		H. M. 3 30		H. M. 3 0		H. M. 2 30		H. M. 2 0		H. M. 1 30		H. M. 1 0		H. M. 0 30	
Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
6	0	5	10	5	6	5	1	4	6	3	9	3	0	2	3	1	6	0	11	0	6	0	2
7	0	6	10	6	5	5	11	5	3	4	4	3	6	2	7	1	9	1	1	0	7	0	2
8	0	7	10	7	4	6	9	6	0	5	0	4	0	3	0	2	0	1	3	0	8	0	2
9	0	8	9	8	3	7	7	6	8	5	8	4	6	3	5	2	4	1	5	0	9	0	3
10	0	9	9	9	2	8	5	7	5	6	3	5	0	3	9	2	7	1	7	0	10	0	3
11	0	10	9	10	1	9	4	8	2	6	10	5	6	4	2	2	10	1	9	0	11	0	3
12	0	11	8	11	0	10	2	8	11	7	6	6	0	4	6	3	1	1	10	1	0	0	4
13	0	12	8	12	0	11	0	9	8	8	2	6	6	4	10	3	4	2	0	1	0	0	4
14	0	13	8	12	11	11	10	10	5	8	9	7	0	5	3	3	7	2	2	1	1	0	4
15	0	14	7	13	10	12	8	11	2	9	5	7	6	5	8	3	10	2	4	1	2	0	5
16	0	15	7	14	9	13	6	11	11	10	0	8	0	6	0	4	1	2	6	1	3	0	5
17	0	16	7	15	8	14	4	12	8	10	8	8	6	6	4	4	4	2	8	1	4	0	5
18	0	17	7	16	7	15	3	13	5	11	3	9	0	6	9	4	7	2	9	1	5	0	5
19	0	18	6	17	6	16	1	14	2	11	10	9	6	7	1	4	10	2	11	1	6	0	6
20	0	19	6	18	5	16	11	14	11	12	6	10	0	7	6	5	1	3	1	1	7	0	6
22	0	21	5	20	3	18	7	16	5	13	9	11	0	8	3	5	7	3	5	1	9	0	7
24	0	23	5	22	1	20	3	17	11	15	0	12	0	9	0	6	1	3	9	1	11	0	7
26	0	25	4	23	11	22	0	19	4	16	3	13	0	9	10	6	8	4	0	2	1	0	8
28	0	27	4	25	9	23	8	20	10	17	6	14	0	10	6	7	2	4	4	2	3	0	8
30	0	29	3	27	7	25	4	22	4	18	9	15	0	11	3	7	8	4	8	2	5	0	9
32	0	31	2	29	5	27	0	23	10	20	0	16	0	12	0	8	2	5	0	2	7	0	10
34	0	33	2	31	3	28	9	25	4	21	3	17	0	12	9	8	8	5	3	2	9	0	10
36	0	35	1	33	1	30	5	26	10	22	6	18	0	13	6	9	2	5	7	2	11	0	11
38	0	37	1	35	0	32	1	28	4	23	9	19	0	14	3	9	8	5	11	3	0	0	11
40	0	39	0	36	10	33	10	29	10	25	0	20	0	15	0	10	2	6	2	3	2	1	0
H. M. 0 0		H. M. 0 30		H. M. 1 0		H. M. 1 30		H. M. 2 0		H. M. 2 30		H. M. 3 0		H. M. 3 30		H. M. 4 0		H. M. 4 30		H. M. 5 0		H. M. 5 30	

TIDES OF BRITISH PORTS.—TABLE 33.

TABLE OF CONSTANTS,

To be added to, or deducted from, the Times and Heights of High Water, as computed from Tables 32 and 32a.

The Ports of Reference and their Tidal Ranges are in Black Figures.

PORTS.	Mean Sprg. Range	Constants. Time.	Constants. Hght.
	Ft. In.	H. M.	Ft. In.
BREST	**19 1**		
Beaumaris	21 3	+6 45	+2 4
Whitehaven and Tarn Point, Solway F.	23 2	+7 30	+4 1
Ile de Seine	17 6	—0 26	—1 7
Ushant	19 4	—0 15	+0 3
St. Malo and Granville	..	+2 22	
Honfleur	23 4	+5 42	+4 3
Guernsey	..	+2 43	
Dieppe	..	+7 19	
Boulogne	24 10	+7 38	+5 9
Cape Grisnez	21 6	+7 40	+2 5
PORTSMOUTH	**12 7**		
Beachy Head	..	—0 21	
Newhaven	..	+0 11	
Shoreham	..	—0 7	
Littlehampton & Selsea	..	+0 5	
Bembridge Point	..	—0 40	
Southampton	..	—1 0	
Cowes	..	—0 55	
Lymington	..	—1 25	
Hurst Camber	..	—1 40	
Needles	..	—1 55	
Christchurch	..	—2 50	
Poole	..	—2 50	
Weymouth	7 0	—5 0	—5 7
Portland Breakwater	7 0	—4 45	—5 7
Portland Bill	..	—5 40	—3 7
West Bay	12 0	..	—0 7
DOVER	**18 8**		
Limerick	16 10	—4 52	—1 10
Tarbert	12 6	—6 15	—4 2
Margate	..	+1 0	
Broadstairs	..	+0 22	
Ramsgate	..	+0 18	
Sandwich	..	+2 10	
Deal	..	+0 5	
Dungeness	..	—0 40	
Rye Bay	..	+0 8	
Ile d' Aix	16 11	—7 52	—1 9
Ile de Noirmoutier	15 11	—8 10	—2 9
St. Nazaire	15 2	—7 32	—3 6
Alderney	17 4	—4 26	—1 4
Cherbourg	16 11	—3 23	—1 9
Havre	22 1	—1 21	+3 5
SHEERNESS	**16 1**		
Chatham	..	+0 15	
Herne Pier	..	—0 25	

PORTS.	Mean Sprg. Range	Constants. Time.	Constants. Hght.
	Ft. In.	H. M.	Ft. In.
LONDON	**19 6**		
Gravesend	..	—0 52	
Purfleet	..	—0 38	
Woolwich	..	—0 20	
Blackwall	20 0	—0 17	+0 6
Greenwich	19 10	—0 14	+0 4
HARWICH	**11 6**		
Yarmouth	5 9	—2 49	—5 9
Lowestoft	7 0	—2 9	—4 6
Orfordness	..	—0 35	
HULL	**20 10**		
Flamborough Head	..	—1 59	
Bridlington	..	—1 50	
Spurn Point	..	—1 9	
Great Grimsby	19 2	—0 53	—1 8
Wainfleet Point	..	—0 29	
Blackeney and Wells	..	—0 9	
Wisbeach Quay	..	+1 0	
Lynn Deep	..	—0 9	
SUNDERLAND	**14 5**		
Dundee	14 7	—0 50	+0 2
Perth Tide Harbour	11 9	+2 50	—2 8
Warkworth	..	—0 24	
Tynemouth Bar	..	—0 22	
North Shields	13 6	+0 9	—0 11
Hartlepool	15 1	+0 6	+0 8
Tees Mouth	..	+0 8	
Whitby	..	+0 23	
Scarboro'	15 10	+0 49	+1 5
LEITH	**16 4**		
Peterhead	..	—1 43	
Aberdeen	..	—1 4	
Stonehaven	..	—0 57	
Montrose	..	—0 40	
Arbroath	..	—0 31	
Berwick	..	—0 2	
Holy Island	..	+0 13	
THURSO	**13 3**		
Banff	..	+4 12	
Tour de Cordouan	13 10	—4 50	+0 7
GREENOCK	**9 9**		
Port Patrick	..	—0 54	
Loch Ryan	..	—0 48	
Campbleton	..	—0 15	
Ayr	8 9	+0 2	—1 0

TIDES OF BRITISH PORTS.—TABLE 33.

TABLE OF CONSTANTS,

To be added to or deducted from the Times and Heights of High Water, as computed from Tables 32 and 32a.

The Ports of Reference and their Tidal Ranges are in Black Figures.

PORTS.	Mean Sprg. Range Ft.	In.	Constants. Time. H.	M.	Constants. Hght. Ft.	In.
GREENOCK	**9**	**9**	..			
Largs	..		−0	11		
Port Glasgow	9	6	+0	10	−0	3
Glasgow	7	9	+1	35	−2	0
LIVERPOOL	**25**	**6**				
Fleetwood	..		−0	12		
St. Bee's Head	..		−0	17		
Annanfoot	..		+0	38		
Port Carlisle	..		+0	48		
Parkgate	..		−0	30		
Douglas	..		−0	4		
PEMBROKE	**21**	**0**				
Tenby	..		−0	2		
Milford Entrance	..		−0	11		
Ramsey Sound	..		+0	3		
Cardigan Bay	..		+0	47		
Aberdovey	..		+2	3		
Port Dynlaen	..		+2	33		
Bardsea Isle	..		+1	33		
Morlaix	23	9	−1	19	+2	9
WESTON SUPER-MARE	**37**	**3**				
St. Ive's	..		−2	10		
Barnstaple	..		−1	7		
Lundy Isle	..		−1	22		
Ilfracombe	..		−1	12		
Bridgewater Bay	35	0	+0	5	−2	3
Portishead	35	9	+0	22	−1	6
Bristol	..		+0	27		
Cardiff	..		+0	5		
Port Talbot	..		−0	26		
Swansea	..		−0	44		
St. Helier's	29	9	−0	39	−7	6
HOLYHEAD	**16**	**1**				
Westport	12	9	−5	14	−3	4
Caernarvon	13	10	−0	38	−2	3
Piel	16	4	−0	57	+0	3
Tobermory	12	11	−4	35	−3	2
Barfleur	17	1	−1	20	+1	0
Dunkirk	16	11	+1	57	+0	10
KINGSTOWN	**11**	**0**				
Donaghadee	11	3	+0	3	+0	3
Carlingford	..		−0	28		
Howth	..		−0	3		
Dublin Bar	13	0	−0	0	+2	0
Wicklow	..		−0	40		
Arklow	..		−2	25		
KINGSTOWN	**11**	**0**				
Dungarvon	12	2	−6	0	+1	2
Crinan	6	1	−5	59	−4	11
Wick	9	9	+0	12	−1	3
BELFAST	**9**	**5**				
Church Bay	..		−2	48		
Ballycastle	2	5	−4	58	7	0
Torr Point (Antrim)	1	8	−1	8	−7	9
Loch Larne	8	0	−0	18	−1	5
SLIGO	**8**	**8**				
Donegal Bar	..		−0	29		
Killebegs	..		−0	29		
Tory Island	..		−0	29		
Sheephaven	11	11	−0	35	+3	3
Londonderry	9	0	−0	31	+0	4
Kinsale	11	7	−1	17	+2	11
Loch Inver	13	11	+0	41	+5	3
East Looe	16	2	−0	34	+7	6
Bordeaux	14	1	+0	50	+5	5
GALWAY	**14**	**10**				
Kilrush	..		+0	7		
Aberystwith	13	5	+2	56	−1	5
Pwllheli	13	8	+3	11	−1	2
Belleisle	14	3	−1	17	−0	7
La Hogue	18	5	−4	7	+3	7
Calais	19	6	+7	14	+4	8
QUEENSTOWN	**11**	**9**				
Dumaire's Bay	10	2	−1	9	−1	7
Bantry	10	2	−1	14	−1	7
Valentia	11	1	−1	19	−0	8
Achilry	10	9	+0	13	−1	0
Wexford	..		+1	29		
New Ross	..		+1	3		
Waterford	13	5	+1	5	+1	8
Dunmore	12	3	+0	26	+0	6
Youghal	12	8	+0	13	+0	11
Inverness	12	2	+7	17	+0	5
DEVONPORT	**15**	**6**				
Lyme Cobb	..		−0	27		
Exmouth	..		+0	52		
Torbay	..		+0	27		
Dartmouth	..		+0	27		
Eddystone	..		−0	18		
Fowey	..		−0	18		
Falmouth	..		−0	18		
Lizard and Mount's Bay	..		−0	53		
Scilly	..		−1	3		

TABLE OF THE MOON'S TRANSIT,

AND DECLINATION AT NOON,

For the Years 1852, 1853 and 1854.

For use see Table 34 in the Remarks on the use of the Tables.

Day of Month.	JANUARY.						FEBRUARY.					
	1852.		1853.		1854.		1852.		1853.		1854.	
	Moon's Transit.	Mn's. Decl. at Noon	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon	Moon's Transit.	Mn's. Decl. at Noon	Moon's Transit.	Mn's. Decl. at Noon.
	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M	Deg.
1	7.37	7	17.32	8	2.27	21	8.39	20	18.51	13	3.37	3
2	8.21	11	18.21	2	3.22	17	9.34	22	19.47	18	4.21	2
3	9.09	15	19.10	3	4.14	12	10.32	22	20.46	21	5.04	8
4	10.00	18	20.03	9	5.01	7	11.31	21	21.45	23	5.48	13
5	10.54	21	20.58	14	5.45	1	12.30	20	22.44	24	6.33	17
6	11.51	22	21.57	19	6.27	4	13.28	16	23.41	23	7.19	21
7	12.50	22	22.58	22	7.09	9	14.23	11		21	8.06	23
8	13.48	21	23.59	24	7.53	14	15.16	6	0.34	18	8.56	25
9	14.45	18		24	8.37	18	16.08	0	1.24	14	9.47	26
10	15.39	14	0.58	23	9.23	21	16.59	5	2.10	9	10.37	25
11	16.32	9	1.54	20	10.12	24	17.51	10	2.53	4	11.27	23
12	17.22	4	2.46	16	11.02	25	18.44	15	3.35	1	12.16	20
13	18.12	1	3.34	12	11.53	25	19.37	18	4.17	6	13.03	16
14	19.03	6	4.18	7	12.43	25	20.31	21	4.58	10	13.49	12
15	19.54	11	5.00	2	13.33	23	21.24	22	5.41	15	14.34	6
16	20.47	15	5.41	3	14.20	19	22.17	22	6.27	18	15.19	1
17	21.41	19	6.22	7	15.06	15	23.07	21	7.14	21	16.05	5
18	22.36	21	7.04	12	15.51	11	23.55	19	8.04	23	16.54	11
19	23.30	22	7.48	16	16.35	5		16	8.57	24	17.47	16
20		22	8.34	19	17.20	0	0.41	13	9.51	24	18.43	20
21	0.23	21	9.24	22	18.08	6	1.24	9	10.45	22	19.43	23
22	1.13	18	10.15	23	18.58	12	2.06	4	11.39	19	20.46	25
23	2.00	15	11.09	24	19.53	17	2.46	0	12.31	15	21.49	26
24	2.45	11	12.03	23	20.53	21	3.27	4	13.22	10	22.49	24
25	3.27	7	12.57	21	21.57	24	4.09	9	14.13	10	23.45	21
26	4.09	3	13.49	18	23.02	26	4.53	13	15.03	1		17
27	4.50	1	14.40	14		25	5.38	16	15.55	7	0.37	11
28	5.31	6	15.30	9	0.05	23	6.28	19	16.48	12	1.25	6
29	6.14	10	16.19	3	1.05	19	7.20	21	..	..	..	..
30	6.59	14	17.08	2	2.00	15	..	..	..	..	..	..
31	7.47	17	17.58	8	2.50	9	..	..	..	..	..	..

TABLE OF THE MOON'S TRANSIT,

AND DECLINATION AT NOON,

For the Years 1852, 1853, and 1854.

For use see Table 34 in the Remarks on the use of the Tables.

Day of Month.	MARCH.						APRIL.					
	1852.		1853.		1854.		1852.		1853.		1854.	
	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit	Mn's. Decl. at Noon.	Moon's Transit	Mn's. Decl. at Noon.
	H. M	Deg.	H. M.	Deg.	H. M	Deg.	H. M.	Deg.	H. M.	Deg.	H. M	Deg.
1	8.15	22	17.43	17	2.12	0	9.48	15	19.29	24	3.03	19
2	9.12	22	18.40	21	2.56	6	10.43	11	20.33	23	3.51	22
3	10.11	20	19.39	23	3.41	11	11.38	5	21.14	20	4.40	25
4	11.09	17	20.32	24	4.25	16	12.33	1	22.00	16	5.30	26
5	12.06	13	21.33	24	5.11	20	13.28	6	22.45	12	6.21	26
6	13.01	8	22.27	22	5.59	23	14.23	11	23.27	7	7.11	25
7	13.56	2	23.16	19	6.48	25	15.20	16		2	8.00	23
8	14.49	3		15	7.39	27	16.17	20	0.09	3	8.48	20
9	15.43	9	0.03	10	8.29	26	17.14	22	0.50	8	9.34	15
10	16.37	14	0.47	6	9.20	24	18.09	23	1.32	12	10.20	10
11	17.32	18	1.30	0	10.08	22	19.01	22	2.16	17	11.06	5
12	18.27	20	2.12	4	10.57	18	19.51	21	3.01	20	11.53	1
13	19 21	22	3.53	9	11.43	13	20.37	18	3.49	23	12.43	7
14	20.14	23	3.36	13	12.29	8	21.21	15	4.38	24	13.35	13
15	21.05	22	4.20	17	13.15	2	22.03	11	5.29	25	14.31	18
16	21.53	20	5.06	21	14.02	3	22.44	7	6.21	24	15.30	22
17	22.38	17	5.55	23	14.51	9	23.25	2	7.13	22	16.33	25
18	23.24	14	6.46	24	15.43	15		22	8.05	19	17.35	26
19	0.00	10	7.38	24	16.38	19	0.06	7	8.56	15	18.35	26
20	0.04	5	8.31	23	17.38	23	0.48	11	9.46	10	19.31	23
21	0.45	1	9.25	21	18.39	25	1.32	15	10.37	4	20.24	19
22	1.26	3	10.17	17	19.40	26	2.19	18	11.29	2	21.12	15
23	2.07	8	11.09	12	20.39	25	3.08	21	11.23	8	21.58	9
24	2.50	12	12.00	7	21.35	22	3.59	22	13.20	14	22.43	4
25	3.35	16	12.52	1	22.27	18	4.53	23	14.20	18	23 27	2
26	4.22	19	13.45	5	23.16	13	5.47	22	15.22	22		8
27	5.12	21	14.39	11		7	6.42	20	16.24	24	0.11	13
28	6.04	22	15.35	16	0.03	2	7.37	17	17.23	25	0.56	17
29	6.59	23	16.34	20	0.48	4	8.30	12	18.19	23	1.43	21
30	7.56	21	17.33	23	1.32	9	9.23	7	19.12	21	2.32	24
31	8.52	19	18.33	24	2.17	14	..	..	..	..	..	..

TABLE OF THE MOON'S TRANSIT,

AND DECLINATION AT NOON,

For the Years 1852, 1853 and 1854.

For use see Table 34 in the Remarks on the use of the Tables.

Day of Month.	MAY.						JUNE.					
	1852.		1853.		1854.		1852.		1853.		1854.	
	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.
	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.
1	10.16	2	20.00	17	3.22	26	11.43	17	20.49	0	4.35	22
2	11.10	4	20.44	13	4.13	26	12.42	21	21.30	5	5.21	18
3	12.05	9	21.27	8	5.03	26	13.41	22	22.12	10	6.05	14
4	13.02	14	22.08	3	5.52	24	14.39	23	22.56	15	6.49	9
5	14.01	19	22.49	2	6.40	21	15.34	22	23.42	18	7.33	3
6	15.00	21	23.31	7	7.26	17	16.26	20	..	21	8.19	2
7	15.57	23	..	11	8.11	12	17.13	17	0.31	24	9.07	8
8	16.53	23	0.13	15	8.57	7	17.58	13	1.21	25	9.59	14
9	17.45	21	0.58	19	9.42	1	18.40	9	2.12	25	10.57	19
10	18.33	20	1.45	22	10.30	5	19.21	5	3.03	23	11.59	23
11	19.19	16	2.34	24	11.21	11	20.02	0	3.54	21	13.05	26
12	20.02	12	3.24	25	12.17	16	20.43	4	4.43	17	14.12	26
13	20.43	8	4.15	25	13.17	21	21.26	8	5.31	13	15.15	25
14	21.24	3	5.07	23	14.20	25	22.11	12	6.18	8	16.13	22
15	22.04	1	5.57	20	15.25	26	22.59	16	7.06	3	17.06	17
16	22.46	5	6.47	16	16.28	26	23.50	19	7.55	3	17.55	12
17	23.30	10	7.36	12	17.26	24	..	22	8.47	9	18.40	6
18	..	14	8.25	6	18.21	21	0.43	23	9.42	14	19.24	0
19	0.16	18	9.14	1	19.11	16	1.38	23	10.42	19	20.07	4
20	1.05	20	10.06	5	19.57	11	2.34	21	11.44	23	20.51	10
21	1.56	22	11.01	11	20.41	5	3.28	19	12.49	24	21.36	15
22	2.49	23	12.00	17	21.25	1	4.21	15	13.53	25	22.23	19
23	3.43	22	13.02	21	22.08	6	5.12	10	14.52	23	23.12	23
24	4.38	21	14.07	24	22.53	11	6.02	5	15.47	20	..	25
25	5.31	18	15.10	24	23.39	16	6.52	0	16.36	16	0.02	26
26	6.24	14	16.10	24	..	20	7.43	6	17.22	11	0.53	36
27	7.15	9	17.05	22	0.27	23	8.35	11	18.05	6	1.43	25
28	8.06	4	17.56	18	1.16	25	9.30	15	18.47	1	2.31	22
29	8.58	2	18.42	14	2.07	26	10.27	19	19.28	4	3.17	19
30	9.50	7	19.26	10	2.57	26	11.25	22	20.10	9	4.02	15
31	10.45	12	20.08	5	3.47	25	..	..	..	..	..	..

TIDES OF BRITISH PORTS.—TABLE 34.

TABLE OF THE MOON'S TRANSIT,

AND DECLINATION AT NOON,

For the Years 1852, 1853, and 1854.

For use see Table 34 in the Remarks on the use of the Tables.

Day of Month.	JULY.						AUGUST.					
	1852.		1853.		1854.		1852.		1853.		1854.	
	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.
	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.
1	12.24	23	20.53	14	4.45	10	13.44	16	22.01	24	5.39	11
2	13.21	23	21.39	18	5.28	5	14.29	12	22.53	25	6.29	16
3	14.15	21	22.27	21	6.12	1	15.12	8	23.45	24	7.24	20
4	15.05	18	23 16	23	6.57	6	15.53	3	..	22	8.23	24
5	15.51	15	..	25	7.46	12	16.34	1	0.36	19	9.28	26
6	16.35	11	0.08	25	8.40	17	17.15	5	1.25	15	10.33	26
7	17.17	7	0.59	24	9.39	22	17.58	10	2.14	10	11.38	25
8	17.58	2	1.51	21	10.43	25	18.43	14	3.01	5	12.38	21
9	18.39	2	2.40	18	11.49	26	19.31	17	3.48	1	13.34	16
10	19.21	7	3.29	14	12.56	26	20.22	20	4.36	6	14.25	11
11	20.04	11	4.16	9	13.58	23	21.15	23	5.26	12	15.13	4
12	20.51	15	5.03	4	14.55	19	22.11	23	6.20	17	15.59	2
13	21.41	19	5.50	2	15.47	14	23.08	22	7.17	21	16.44	8
14	22.33	21	6.39	7	16.36	8	..	21	8.17	25	17.30	13
15	23.29	22	7.31	13	17.21	2	0.05	17	9.18	25	18.16	18
16	..	23	8.27	18	18.05	4	1.00	13	10.19	25	19.04	21
17	0.25	22	9.27	22	18.49	9	1.53	8	11.18	22	19.54	24
18	1.21	19	10.29	24	19.34	14	2.45	2	12.13	19	20.45	26
19	2.16	16	11.33	25	20.21	18	3.36	3	13.03	15	21.35	26
20	3.09	12	12.35	24	21.09	22	4.28	8	13.50	10	22.24	26
21	4.00	6	13.32	21	21.59	25	5.21	13	14.35	4	23.12	24
22	4.50	1	14.25	17	22.49	26	6.15	18	15.18	1	23.58	21
23	5.40	4	15.14	13	23.39	26	7.11	21	16.01	6	..	17
24	6.31	9	15.59	8	..	25	8.07	23	16.44	11	0.43	12
25	7.24	14	16.42	2	0.28	23	9.03	23	17.28	15	1.26	7
26	8.19	18	17.24	2	1.15	20	9.57	22	18.14	19	2.09	2
27	9.15	21	18.06	7	2.01	16	10.49	20	19.02	22	2.52	4
28	10.13	23	18.49	12	2.44	11	11.38	17	19.52	24	3.37	10
29	11.09	23	19.34	17	3.27	6	12.24	13	20.44	25	4.25	15
30	12.04	22	20.21	20	4.09	1	13.07	9	21.36	25	5.17	20
31	12.56	19	21.10	22	4.53	5	13.49	5	22.27	23	6.13	23

TABLE OF THE MOON'S TRANSIT,

AND DECLINATION AT NOON,

For the Years 1852, 1853, and 1854.

For use see Table 34 in the Remarks on the use of the Tables.

Day of Month.	SEPTEMBER.						OCTOBER.					
	1852.		1853.		1854.		1852.		1853.		1854.	
	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit	Mn's. Decl. at Noon.	Moon's Transit	Mn's Decl. at Noon.
	H. M	Deg.	H. M.	Deg.	H. M	Deg.	H. M.	Deg.	H. M.	Deg.	H. M	Deg.
1	14.30	0	23.18	21	7.14	26	14.33	12	23.35	9	8.10	24
2	15.11	4	..	17	8.17	27	15.18	16	..	3	9.07	20
3	15.53	9	0.07	12	9.21	26	16.05	19	0.24	3	10.00	15
4	16.37	13	0.56	7	10.21	23	16.55	22	1.15	9	10.50	9
5	17.23	17	1.44	1	11.18	19	17.47	23	2.08	15	11.38	3
6	18.11	20	2.33	5	12.11	13	18.40	23	3.05	19	12.25	3
7	19.03	22	3.23	11	13.01	7	19.35	23	4.04	23	13.11	9
8	19.57	23	4.16	16	13.49	1	20.29	21	5.05	25	13.59	14
9	20.53	23	5.11	20	14.35	5	21.23	17	6.05	25	14.48	19
10	21.49	21	6.10	23	15.21	11	22.16	12	7.04	24	15.38	23
11	22.45	19	7.10	25	16.09	16	23.10	7	7.59	21	16.29	25
12	23.39	15	8.10	25	16.58	20	..	1	8.51	17	17.20	26
13	..	10	9.09	23	17.47	24	0.04	4	9.39	13	18.11	27
14	0.33	4	10.04	20	18.38	26	0.59	10	10.24	7	19.00	26
15	1.26	1	10.55	16	19.28	27	1.55	15	11.07	2	19.47	23
16	2.19	7	11.43	11	20.18	26	2.54	19	11.50	2	20.33	20
17	3.13	12	12.28	6	21.07	25	3.53	22	12.32	8	21.17	16
18	4.08	17	13.11	1	21.54	22	4.52	23	13.16	13	22.00	11
19	5.05	20	13.54	4	22.39	18	5.49	23	14.01	17	22.44	5
20	6.02	22	14.37	9	23.23	14	6.43	22	14.48	21	23.29	1
21	6.59	23	15.21	14	..	9	7.33	19	15.36	23	..	6
22	7.54	23	16.07	18	0.06	3	8.20	15	16.26	25	0.16	12
23	8.46	21	16.54	21	0.50	2	9.04	11	17.16	25	1.07	18
24	9.35	18	17.43	24	1.35	8	9.46	7	18.07	25	2.02	22
25	10.21	14	18.34	25	2.22	14	10.27	2	18.57	23	3.01	25
26	11.05	10	19.25	25	3.13	19	11.08	2	19.46	20	4.02	27
27	11.47	6	20.17	24	4.08	23	11.49	6	20.34	16	5.05	27
28	12.28	1	21.07	22	5.07	26	12.31	11	21.22	11	6.05	25
29	13.09	3	21.57	18	6.08	27	13.15	15	22.11	6	7.02	21
30	13.50	8	22.46	14	7.11	26	14.02	18	23.01	0	7.55	17
31	..	..	..	..	..	..	14.51	21	23.54	6	8.45	11

TIDES OF BRITISH PORTS.—Table 34.

TABLE OF THE MOON'S TRANSIT,

AND DECLINATION AT NOON,

For the Years 1852, 1853 and 1854.

For use see Table 34 *in the Remarks on the use of the Tables.*

Day of Month.	NOVEMBER.						DECEMBER.					
	1852.		1853.		1854.		1852.		1853.		1854.	
	Moon's Transit.	Mn's. Decl at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon.	Moon's Transit.	Mn's. Decl. at Noon	Moon's Transit.	Mn's. Decl at Noon	Moon's Transit.	Mn's. Decl. at Noon.
	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M.	Deg.	H. M	Deg.
1	15.41	23	..	13	9.32	5	16.15	22	0.33	24	9.45	11
2	16.34	24	0 51	18	10.17	1	17.06	19	1.38	25	10.32	16
3	17.27	23	1.51	22	11.03	7	17.57	16	2.44	25	11.20	21
4	18.19	22	2.54	25	11.50	13	18.46	11	3.45	23	12.11	24
5	19.12	19	3.57	26	12.38	17	19.36	6	4.42	20	13.02	27
6	20.03	15	4.58	25	13.28	22	20.26	0	5.34	16	13.54	27
7	20.55	10	5.56	22	14.19	25	21.19	5	6.21	11	14.45	26
8	21.47	4	6.49	19	15.11	26	22.15	10	7.05	5	15.34	25
9	22.40	1	7.37	14	16.02	27	23.13	16	7.47	0	16.20	22
10	23.36	7	8.23	9	16.52	27	..	20	8.29	5	17 04	19
11	..	13	9.06	4	17.40	24	0.15	23	9.12	10	17.46	14
12	0.34	18	9.48	1	18.26	21	1.17	24	9.55	15	18.28	9
13	1.35	22	10.30	6	19.10	17	2.18	23	10.40	19	19.10	4
14	2.37	23	11.13	11	19.53	13	3.15	22	11.27	22	19.54	2
15	3.37	24	11.57	16	20.36	7	4.08	18	12.16	24	20.41	8
16	4.34	23	12.43	20	21.19	2	4.57	15	13.07	26	21.32	13
17	5.28	20	13.31	23	22 06	4	5.42	10	13.57	25	22.29	18
18	6.17	17	14.21	25	22.55	10	6.24	5	14.47	24	23.31	23
19	7.03	13	15.11	26	23.49	16	7.05	0	15.35	22	..	26
20	7.45	8	16.01	25	..	21	7.45	4	16.22	19	0.36	27
21	8.27	4	16 51	24	0.48	24	8.27	9	17.07	14	1.43	26
22	9.07	1	17.39	21	1.51	27	9.10	13	17.52	9	2.46	23
23	9.48	5	18 25	17	2.55	27	9.54	17	18.38	4	3.45	19
24	10.30	10	19.12	13	3.59	25	10.42	20	19.25	1	4.38	14
25	11.13	14	19 59	8	4.58	22	11.32	23	20.15	7	5.28	8
26	11.59	18	20.47	2	5.52	18	12.25	23	21.09	13	6.14	2
27	12.47	21	21.37	4	6.43	12	13.18	24	22.09	18	6.59	4
28	13.38	23	22.31	10	7.30	7	14.11	23	23.13	22	7.44	10
29	14.30	24	23.30	15	8.15	0	15.04	21	..	25	8.29	15
30	15.23	24	..	20	9.00	5	15.54	17	0.20	26	9.17	19
31	..	..	..	..	..	..	16.43	13	1.25	24	10.06	23

TABLE OF THE MOON'S HORIZONTAL PARALLAX

AT NOON,

For the Years 1852, 1853, and 1854.

The following Table gives the Moon's Parallax for correcting the Tidal Heights. Every fifth day only is given; and for the intermediate days sufficient accuracy will be obtained by averaging the intervals. *When the Horizontal Parallax is 57 minutes, there is no correction, as the Tables 32, &c., are computed at this Parallax.*

Month	Day.	1852.	1853.	1854.	Month	Day.	1852.	1853.	1854.
		M. Sec.	M. Sec.	M. Sec.			M. Sec.	M. Sec.	M. Sec.
JANUARY.	1	54 46	58 15	60 9	JULY.	1	58 22	54 8	55 23
	6	58 1	59 58	55 39		6	55 7	54 50	59 33
	11	59 34	57 52	54 0		11	54 29	57 15	61 6
	16	58 6	54 34	55 7		16	57 11	60 3	56 57
	21	55 46	54 56	57 56		21	59 14	59 17	54 10
	26	54 7	57 37	60 46		26	58 44	55 23	54 23
FEBRUARY.	1	56 45	59 14	57 29	AUGUST.	1	55 52	54 32	57 32
	6	60 19	58 20	54 18		6	54 12	56 54	60 56
	11	59 1	55 25	54 51		11	56 10	59 1	58 58
	16	56 3	54 21	57 10		16	59 40	59 23	54 54
	21	54 13	57 05	59 26		21	59 16	56 35	54 14
	26	54 37	59 38	59 21		26	56 44	54 17	56 3
MARCH.	1	57 33	59 23	57 19	SEPTEMBER.	1	54 17	56 25	59 23
	6	61 8	57 27	54 23		6	54 51	59 6	59 58
	11	58 39	55 2	55 14		11	58 51	59 5	56 18
	16	55 8	54 17	58 0		16	60 42	57 9	54 12
	21	53 55	57 19	59 15		21	57 31	54 38	55 45
	26	55 5	60 32	58 26		26	54 47	54 48	58 12
APRIL.	1	60 5	58 5	55 3	OCTOBER.	1	53 59	58 23	59 29
	6	60 43	55 20	54 32		6	56 1	60 7	58 7
	11	56 19	54 2	57 35		11	60 29	57 57	54 58
	16	54 1	55 36	59 46		16	60 15	55 25	54 40
	21	54 28	60 1	58 28		21	56 1	54 5	57 35
	26	57 11	60 34	56 5		26	54 1	55 57	59 23
MAY.	1	60 50	56 36	54 13	NOVEMBER.	1	54 51	60 46	58 11
	6	59 16	54 15	55 30		6	58 24	59 19	55 41
	11	55 3	54 13	59 33		11	61 19	55 49	54 13
	16	54 5	57 4	60 7		16	57 53	54 6	56 31
	21	55 44	61 10	57 1		21	54 24	54 39	59 59
	26	58 35	59 28	54 40		26	54 14	58 28	59 8
JUNE.	1	60 9	54 44	54 26	DECEMBER.	1	56 10	61 26	56 30
	6	56 34	54 1	57 55		6	59 33	57 59	54 27
	11	54 10	55 42	61 14		11	60 20	54 36	54 34
	16	55 25	59 25	58 30		16	56 15	54 1	58 17
	21	57 54	60 52	55 1		21	54 5	55 47	61 0
	26	59 30	56 51	53 57		26	55 20	59 53	58 2

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